National Aeronautics and Space Administration

OUR EYE ON THE SUN

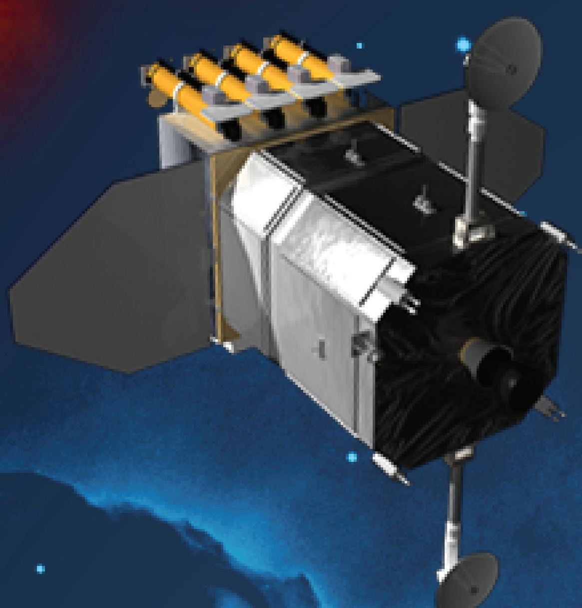
THE SCIENCE OF THE SUN

Secondary Learning Unit

Educational Product	
Educators	Grades 7-12

EG-2010-01-032-GSFC

SDO | solar dynamics observatory



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Introduction

Understanding the relationship between Earth and the Sun is a fundamental concept in science. In this unit students focus on the Sun as the cause of seasons on earth, and the study of the Sun its self. Beginning with the seasons, students explore the relationship between the Sun and Earth in space. With that foundation in place, students learn about solar features, how we study them, and then how we use the electromagnetic spectrum to study other objects in space. Using a clear constructivist framework, each lesson builds on the next to create an understanding of the Sun's place in space.

Justification

An understanding of the Sun/earth relationship, as well as the electromagnetic spectrum is necessary for preventing and dispelling misconceptions that surface in later grades. This unit seeks to lay a solid foundation of science that teachers can build on through high school earth and physical science. In addition to providing clear scientific concepts, this unit satisfies all national standards addressing Sun/earth relationships and solar energy, as well as physical science standards.

How to Use this Guide

This guide was written in the interactive notebook format, one developed to facilitate inquiry learning, constructivist theory, and a brain based model. The following is a discussion about the work behind the model, what you will find in the lessons, and how they apply to the classroom.

Inquiry is:

- **Meaning:**
  Science inquiry in education is founded on the principles of brain-based learning. The search for meaning is innate. Maslow explained this in his hierarchy of needs. Individuals look for meaning in relation to their own experiences, what they value, and how the new information aligns with those factors. The search for meaning in science classrooms can be stimulated by questioning, hypothesizing, and by exploring unexpected results.

- **Connections:**
  The brain is designed to find connections. An effective science inquiry experience is rich in authenticity and purpose, clearly connecting to other aspects of both science and life. Students will retain and be able to recall facts and information easily when they are linked to multiple sources.

- **Engagement:**
  Students who participate in true science inquiry take ownership of their learning. Introducing challenge and creating a sense of wonder are easy and efficient ways to engage the mind. But remember: Just because something is "Hands on" doesn't mean it's "Minds on." Inquiry doesn't always mean student directed, open-ended research projects. Students learn in a variety of ways, each modality needs to be included to engage as many students as possible.

The ABC's of Inquiry
So how can we apply this in every single lesson/activity/curriculum we create? The answer is you can't. You'd go nuts. But you can structure your resources in a way that lends itself to the creation of such products. Here's how:

- **Activity Before Concept. (ABC)**
  Engage students in the concept to be learned without priming them first. Don't tell them what you are going to teach them, let them figure it out for themselves. Through discussion following the activity the concept can be teased out. What was in their subconscious will emerge and become a solid concept that is not only connected to their prior knowledge, but is now a rewarding "Aha!" moment.

- **Concept Before Vocabulary: (CBV)**
  Explore the concept. As you explore students will realize a need for the words to accurately describe it. Identify the need, then give them the tools. No more rote memorization of vocabulary, the meaning and application of words is now owned by the students.

Why the ABC's? To engage, to wonder, to challenge, and to link. Designing resources with this in mind can't avoid including inquiry.

The Interactive Notebook
To further put this into practice, consider this format: The Interactive Notebook. The interactive notebook goes beyond traditional classroom record keeping. It provides a home and structure for the connections being made in an inquiry-based classroom or program.

- The "Predict" portion of the notebook or lesson is to engage your students and to tap into their prior knowledge. This section should be student driven. There is no right answer.

- The "Method" section is the meat of the concept. It could be notes, an investigation, lab results, or drawings. It is driven by the teacher to whatever degree is required by the lesson. More structured for "directed inquiry" and more open ended for "true inquiry."

- The “Live-it” portion is the wrap up, the application and the conclusion. It asks students to prove that they’ve learned by applying the concept. Higher order thinking tasks should be assigned, such as evaluation, application or synthesis. This section should be student driven as well, with products being evaluated by the teacher.

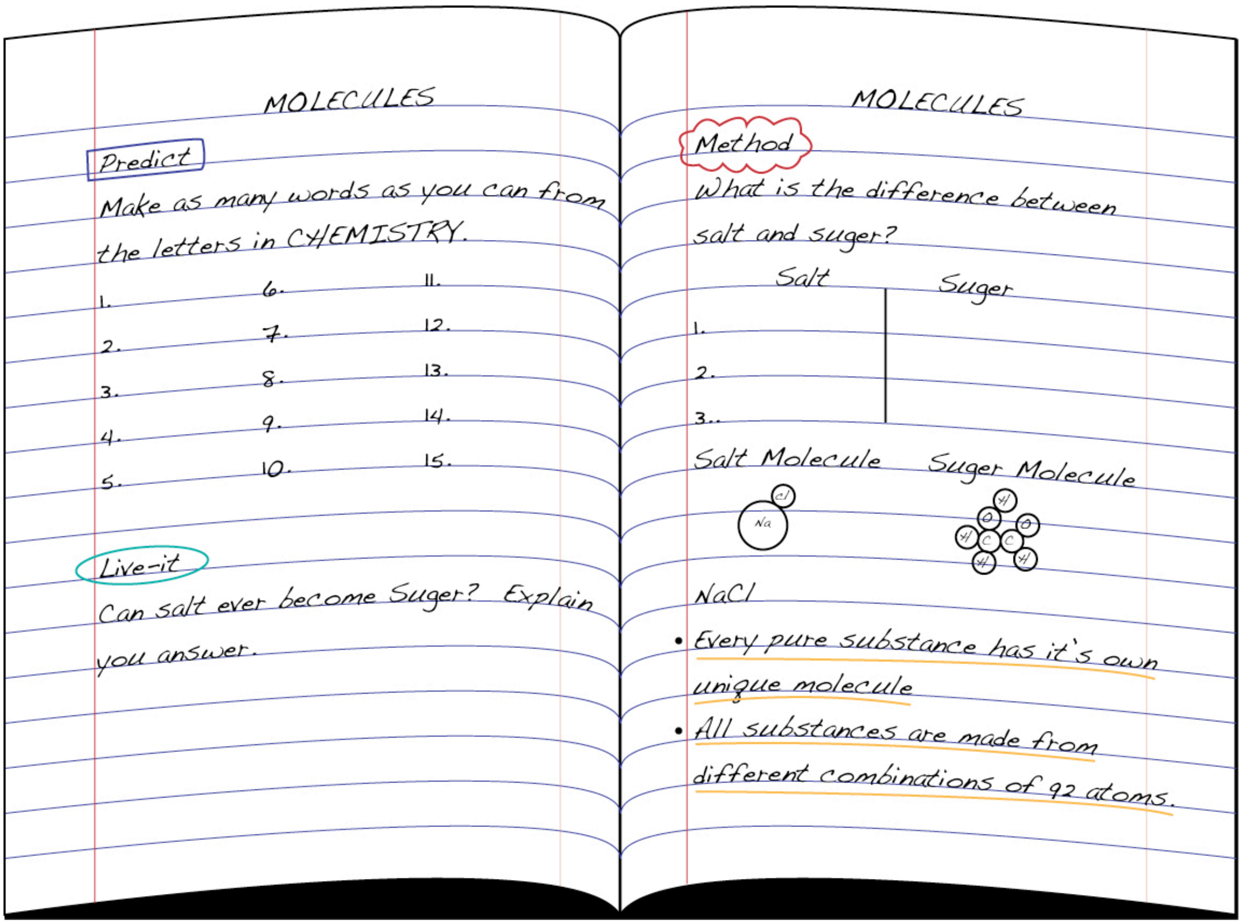


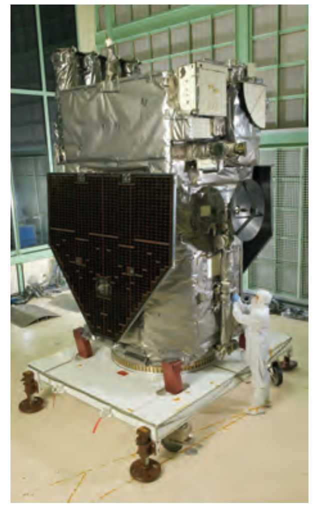
Fig. 1: Example of interactive notebook

So why design lessons using the interactive notebook format? Predict, Method and Live-it are analogous to engagement, connection and meaning.

Science is not a foreign subject – its internal to every student. Exploration is as natural as breathing. The focus needs to stop being on creating the next Einstein, but on showing students that science is a welcomed part of their every day lives.

NOTES:

The SDO Spacecraft



SDO nearing completion in 2009

SDO is one of the largest solar observing spacecraft ever placed into orbit. Its solar panels are 6.5 meters (21.3 ft) wide when extended and will provide SDO all the power it needs from the Sun. The specially-filtered telescopes will take images of the Sun with 10 times greater resolution than high-definition television. Total mass of the spacecraft at launch is 3,100 kg (6,800 lb).

Data for Everyone

SDO's dedicated ground station in Las Cruces, NM

Each day in orbit, SDO will gather as much as 1.4 terabytes of data. Scientists, educators, and members of the general public will be able to browse this huge volume of data giving researchers and others a powerful new way to view the Sun.

SDO is part of the Living With a Star Program within NASA's Heliophysics Division

OUR EYE ON THE SUN
SOLAR DYNAMICS OBSERVATORY
NASA
HMI • AIA • EVE

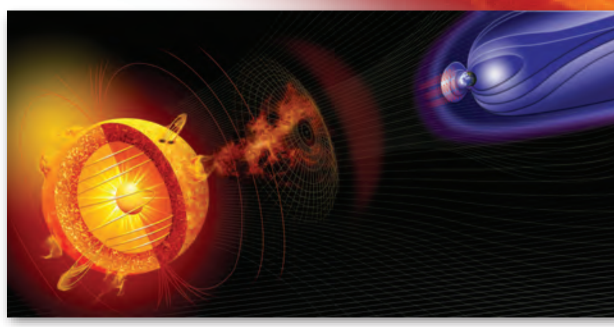
Visit us on the Web at:
http://sdo.gsfc.nasa.gov

For information on Heliophysics programs and missions, see:
http://nasascience.nasa.gov/heliophysics

NP-2009-10-103-GSFC

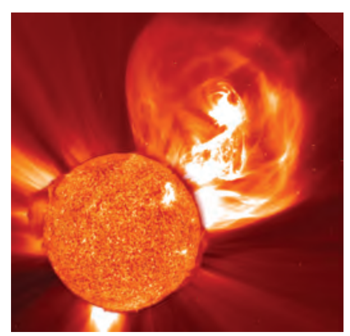
SDO: Our Eye on the Sun

SDO Science


Solar storm impacting Earth and its magnetic shield

Solar activity and variability are key concerns of our modern, increasingly technological society. Solar flares and coronal mass ejections can disable satellites, cause power grid failures, and disrupt GPS communications. Furthermore, because the Sun is so powerful, even small changes in its irradiance could have effects on climate.

The Solar Dynamics Observatory (SDO) is designed to probe solar variability in a way that no other mission can match.


Solar storm shooting into space

High-speed cameras on SDO will take rapid-fire snapshots of solar flares and other magnetic activity. This will have the same transformative effect on solar physics that the invention of high-speed photography had on many sciences in the 19th century.

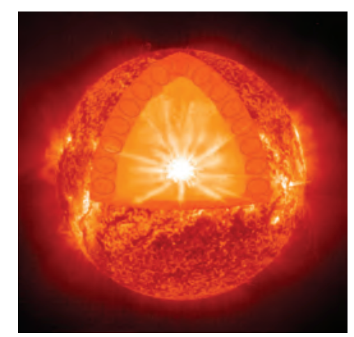
SDO doesn't stop at the stellar surface. A sensor on the observatory can actually look inside the Sun at the very source of solar activity—the solar dynamo itself. There SDO will find vital clues to the mystery of the solar cycle and help scientists predict the future of solar activity.

SDO Instruments


Magnetic activity on the surface of the Sun

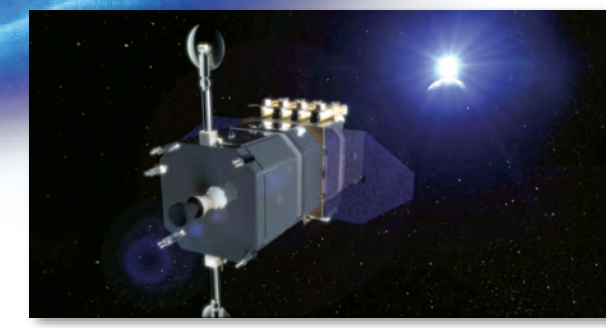
The Solar Dynamics Observatory has three main instruments.

- The ***Extreme Ultraviolet Variability Experiment (EVE)*** will measure fluctuations in the Sun's ultraviolet output. EUV radiation from the Sun has a direct and powerful effect on Earth's upper atmosphere, heating it, puffing it up, and breaking apart atoms and molecules.


SDO will study the solar interior

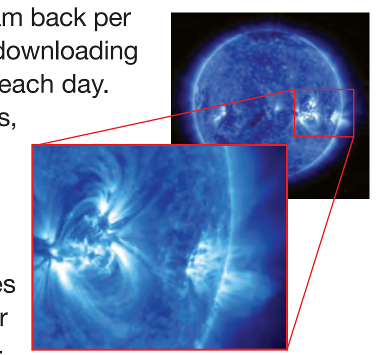
- The ***Helioseismic and Magnetic Imager (HMI)*** will map solar surface magnetic fields and peer beneath the Sun's opaque surface using a technique called helioseismology. A key goal of this experiment is to decipher the physics of the Sun's magnetic dynamo.
- The ***Atmospheric Imaging Assembly (AIA)*** is a battery of four telescopes designed to photograph the Sun's surface and atmosphere. AIA filters cover 10 different wavelength bands, or colors, selected to reveal key aspects of solar activity.

An Avalanche of Data


SDO's orbit will allow continuous observations of the Sun

Imagine watching a high-definition movie that never stops. The enormous screen is filled with the raging Sun, unleashing huge solar flares and billion-ton clouds of hot plasma. The amount of data and images SDO will beam back per day is equivalent to downloading half-a-million songs each day.

By some estimates, SDO will transmit as much as 50 times more science data than any mission in NASA history. Images with 10 times greater resolution than high-definition television recorded every 0.75 seconds will reveal every nuance of solar activity. Because such fast cadences have never been attempted before by an orbiting observatory, the potential for discovery is great.


SDO's images are super HD

The data rate is equally great. To handle the load, NASA has set up a pair of dedicated radio antennas near Las Cruces, New Mexico. SDO's geosynchronous orbit will keep the observatory in constant view of the two 18-meter dishes around the clock for the duration of the observatory's five-year prime mission. Not a single bit should be lost.

Lesson Matrix

Lesson	Objectives	Key Concepts	Vocabulary	Activity	Materials
The Size of the Sun	Students will be able to use a pinhole camera to calculate the Sun's diameter. Students will be able to calculate a scale model using the distance between Earth and the Sun.	The Sun is the largest body in our solar system, accounting for 90% of its mass. Pinhole cameras are a safe way to observe the Sun. The Sun's diameter can be calculated using the ratio of Earth's size and distance to that of the Sun. A scale model can then be calculated.	Diameter Ratio Scale Model	Students will construct a pinhole camera. Using the projected image of the Sun they can calculate its diameter. After calculating the diameter of the Sun, students will create a classroom sized scale model of the Sun and Earth.	One pin Per group: Two index cards Meter stick Calculator
Solar Dynamics Observatory Brochure	Students will be able to define foci and ellipse. Student will be able to earth's orbit as an ellipse. Students will be able to explain that Earth is closest to the Sun in December, and farthest away from the Sun in June.	Earth's orbit around the Sun is an ellipse. An ellipse is a shape with two foci (focus, singular, foci, plural). The closer together the foci, the more similar to a circle the ellipse. The foci around which earth orbits are both very close together, both located inside the Sun. Earth's orbit brings it closest to the Sun in January, with a difference of only 5.1 million miles.	Ellipse Focus Foci Apparent Actual	Students draw a circle with a single focus, an ellipse with two foci close together, and an ellipse with two foci far apart. They compare the shapes. Students measure the Sun in four images each taken in a different season, comparing the apparent size of the Sun in each image to determine when Earth is closest to the Sun.	Per group: 6 inch length of string tied in a loop. Two tacks Square of corrugated cardboard. Telescope images of the Sun in each season. Ruler

Lesson	Objectives	Key Concepts	Vocabulary	Activity	Materials
Light, Directly	Students will be able to explain that direct Sunlight transfers more energy to an area than indirect Sunlight. Students will be able to explain that light hitting Earth perpendicularly is considered "direct" light, and light hitting Earth at a low angle is considered "indirect" light.	The energy received on any portion of Earth is a fraction of the total energy that comes from the Sun. Because Earth is a sphere, areas tilted away from the Sun receive indirect Sunlight, Sunlight that has been spread out over a larger surface area. Areas directly facing the Sun receive direct Sunlight – more energy from the Sun and because of that, are warmer.	Direct Indirect Percentage Fraction Energy	Students review Earth's position relative to the Sun. Students then use graph paper to investigate the affect of angle on area illuminated. The fraction of "light" on each square is then calculated and compared.	Light bulb and power source Globe For each student: Scissors Sun Angle Analyzer printed on cardstock Brad fastener
Graphing the Globe	Students will be able to explain that day length and temperature are related. Students will be able to create and analyze a graph.	The length of day varies with latitude and with time of year. The tilt of Earth causes the northern hemisphere to receive the most Sunlight in June, resulting in higher temperatures.	Minimum Maximum Analyze Correlate Conclude	The class is split into two different teams, groups on the first team graph hours of Sunlight versus month for a number of latitudes. The second group graphs temperature versus month for the same latitudes. Teams compare data and draw conclusions from their analysis.	Data sets for each group Graph handouts Colored pencils Blank graph transparency

Lesson	Objectives	Key Concepts	Vocabulary	Activity	Materials
Kinesthetic Astronomy	Students will be able to explain the spatial relationship between Earth and the Sun. Students will be able to model the movement of Earth around the Sun. Students will be able to define Solstice and Equinox	Earth rotates and revolves counterclockwise around the Sun. Earth is also tilted towards the north star, Polaris. Twice a year Earth's tilt is parallel to the Sun and every area on earth experiences an equal number of daylight hours. Twice a year the northern hemisphere is tilted either towards or away from the Sun. These days are called a solstice. The changes in earth's position cause seasons.	Solstice Equinox Rotation Revolution Orbit	Students act out the motions of Earth around the Sun over the course of one year, including the tilt, solstice and equinox	Signs, one of each month. Object to represent the Sun Globe(s) Flashlight Object or sign to represent Polaris Optional: "East" and "West" popsicle sticks Optional: Zodiac constellation signs Optional: NASA Solar Pizza
Measuring Time	Students will be able to define a day as one rotation of Earth. Students will be able to explain that time can be measured by the position of the Sun in the sky as Earth rotates. Students will be able to explain that shadows are indicators of Earth's rotation and can be used to measure time.	Sundials work by casting a shadow on the ground that moves as Earth rotates on its axis. The Sun appears to move across the sky from east to west, so the shadow will move across the dial from west to east. Students will be able to model the motion of shadows on the ground by simulating Earth over the course of one day.	Gnomon Clockwise Counter clockwise Rotate Revolve	Students model the rotation of Earth over one day, holding a flashlight for the Sun and a blow up globe with objects attached to make it 3D, and record their observations. They then take those observations and create a "device" that will let them track time. Students conclude by taking them outside to test their effectiveness.	Blow up globes 6 Tiny plastic people and trees East and West Popsicle sticks Tape Flashlight Scissors Card stock Sundial pattern

Lesson	Objectives	Key Concepts	Vocabulary	Activity	Materials
Solar Observations	Students will be able to identify Sunspots and prominences on the Sun. Students will be able to explain that the Sun moves across the sky in a predictable motion.	The Sun is a dynamic ball of plasma, fusing hydrogen and helium gasses and releasing the energy through radiation. It has distinct features caused by electromagnetic forces, which include Sunspots and prominences. The Sun also has a predictable movement across the sky, which can be measured and recorded.	Sunspot Prominence Disc	Students spend the class period outdoors using pinhole cameras to make solar observations and look for Sunspots. Students also mark the position of shadows on the ground.	Per group: Pinhole cameras – meter stick and two index cards. Solar telescope (Or filter) Eclipse Glasses Solar feature worksheets.
The Sun and Magnetic Fields	Students will be able to map a magnetic field. Students will be able to explain that invisible fields surround magnets. Students will be able to explain that magnetic fields on the Sun are visible in Sunspots.	A field is an abstract means of describing how an object influences the space and objects around it. A magnet generates a field that can be measured both in direction and magnitude, a vector quantity. Earth has a magnetic field that can be detected, as does the Sun.	Magnetic Force Field Dipole Orientation	Students will simulate Sunspots by using iron filings to map magnetic fields around bar a magnet. Students map the magnetic field surrounding two dipole magnets, both parallel and anti-parallel alignment. Students apply vector measurements to their field maps. Then students examine the field arrangement around complex arrangements of the dipole magnets.	Per group: Large sheets of paper Two cow magnets Iron Filings Worksheet

Lesson	Objectives	Key Concepts	Vocabulary	Activity	Materials
Studying Light: Seeing the Invisible	Students will be able to describe the electromagnetic spectrum. Students will be able to explain that other types of light can be detected, even though we can't see it.	The electromagnetic spectrum describes the range of energy, from low to high frequency. Visible light detected by our eyes is only a small part of that spectrum. Other types can be detected with other means.	EM Spectrum Radiation Light Visible Ultra Violet Radio	Students begin by using a clothesline to model a logarithmic scale. Then they add in the electromagnetic spectrum. Finally, students conduct several simple tests to detect other types of radiation.	Clothes line Printed cards Per group: IR remote control UV beads Sun screen UV light or window
Studying Light: Spectro-scopes	Students will be able to explain that visible light can be split into a spectrum, and that different elements give off different spectrum when excited.	Individual elements can be identified by examining their emission spectra. Astronomers use the same technique. By looking at the spectra from stars or galaxies their composition, temperature, speed and distance can be inferred.	EM Spectrum Radiation Light Visible Emission	Students build their own spectroscopes, learn about graphing the spectra, and then identify elements in gas tubes using their spectra. The activity concludes with students looking at spectra of celestial objects.	Spectral light tubes Per student: Cereal box Construction supplies Diffraction gradients Worksheets

Lesson	Objectives	Key Concepts	Vocabulary	Activity	Materials
Sounds of the Sun	Students will be able to explain the Doppler effect and the relationship between speed and direction of source, and frequency of sound waves. Students will be able to explain how the Doppler shift can be used to gather information about objects in space including the Sun. Students will be able to calculate the change in frequency of sound emitted by a moving object using the Doppler equations.	When a source emitting waves, sound or light, is moving, the frequency of those waves changes. When the source is moving towards the observer, the frequency increases. When it is moving away, it decreases. With sound this is observed as a change in pitch, with light the spectrum is shifted. The faster the motion, the greater the shift. This can be used by astronomers to measure the speed and distance of objects in space. SDO's HMI instrument uses it to find waves on the surface of the Sun, and track their motion.	Frequency Wave Source Doppler Effect	Students begin by simulating the noise made by a passing siren. After leaning that the change in pitch results from movement they investigate the definition of frequency. Students conclude by calculating the change in frequency heard when they simulated the noise of the passing siren, and learn how this applies to light and the study of astronomy.	Doppler ball Meter Stick Calculators Ramp, 4ft long. Small balls (malted milk balls or marbles)

Abbreviated Unit

Lesson	Objectives	Key Concepts	Vocabulary	Activity	Materials
Earth's Orbit	Students will be able to define foci and ellipse Student will be able to earth's orbit as an ellipse. Students will be able to explain that Earth is closest to the Sun in December, and farthest away from the Sun in June	Earth's orbit around the Sun is an ellipse. An ellipse is a shape with two foci (focus, singular, foci, plural). The closer together the foci, the more similar to a circle the ellipse. The foci around which earth orbits are both very close together, both located inside the Sun. Earth's orbit brings it closest to the Sun in January, with a difference of only 5.1 million miles.	Ellipse Focus Foci Apparent Actual	Students draw a circle with a single focus, an ellipse with two foci close together, and an ellipse with two foci far apart. They compare the shapes. Students measure the Sun in four images each taken in a different season, comparing the apparent size of the Sun in each image to determine when Earth is closest to the Sun.	Per group: 6 inch length of string tied in a loop. Two tacks Square of corrugated cardboard. Telescope images of the Sun in each season. Ruler
Light, Directly	Students will be able to explain that direct Sunlight transfers more energy to an area than indirect Sunlight.	The energy received on any portion of Earth is a fraction of the total energy that comes from the Sun. Because Earth is a sphere, areas tilted away from the Sun receive indirect Sunlight, Sunlight that has been spread out over a larger surface area. Areas directly facing the Sun receive direct Sunlight – more energy from the Sun and are warmer.	Direct Indirect Percentage Fraction Energy	Students compete to see which team can melt an ice cube fastest using only a lamp. Students use graph paper to trace the area illuminated by a flashlight at a 90-degree angle to the paper, and at a 45-degree angle to the paper. The fraction of "light" on each square is then calculated and compared.	Flashlights Graph paper Heat lamps Ice cubes Stop watches

Lesson	Objectives	Key Concepts	Vocabulary	Activity	Materials
Kinesthetic Astronomy	Students will be able to explain the spatial relationship between Earth and the Sun. Students will be able to model the movement of Earth around the Sun. Students will be able to define Solstice and Equinox	Earth rotates and revolves counterclockwise around the Sun. Earth is also tilted towards the north star, Polaris. Twice a year Earth's tilt is parallel to the Sun and every area on earth experiences an equal number of daylight hours. Twice a year the northern hemisphere is tilted either towards or away from the Sun. These days are called a solstice. The changes in earth's position cause seasons.	Solstice Equinox Rotation Revolution Orbit	Students act out the motions of Earth around the Sun over the course of one year, including the tilt, solstice and equinox	Signs, one of each month. Object to represent the Sun Globe(s) Flashlight Object or sign to represent Polaris Optional: "East" and "West" popsicle sticks Optional: Zodiac constellation signs Optional: NASA Solar Pizza
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Lesson	Objectives	Key Concepts	Vocabulary	Activity	Materials
Magnetometers and Magnetic Fields	Students will be able to create a magnetometer and explain its function. Students will be able to explain that invisible fields surround magnets. Students will understand that Earth has an ambient magnetic field.	A field is an abstract means of describing how an object influences the space and objects around it. A magnet generates a field that can be measured both in direction and magnitude, a vector quantity. Earth has a magnetic field that can be detected, as does the Sun.	Magnetic Force Field Dipole Orientation Dynamo	Students will construct a magnetometer then use it to measure the magnetic field around a dipole magnet..	Per group: 2 Liter soda bottle 2ft of sewing thread Small bar magnet 3x5 index card 1 mirrored sequin 1 lamp Scissors 1 Meter stick Super/hot glue 1in of soda straw Large sheet of paper Tape
Studying Light: Spectroscopes	Students will be able to explain that visible light can be split into a spectrum, and that different elements give off different spectrum when excited.	Individual elements can be identified by examining their emission spectra. Astronomers use the same technique. By looking at the spectra from stars or galaxies their composition, temperature, speed and distance can be inferred.	EM Spectrum Radiation Light Visible Emission	Students build their own spectroscopes, learn about graphing the spectra, and then identify elements in gas tubes using their spectra. The activity concludes with students looking at spectra of celestial objects.	Spectral light tubes Per student: Cereal box Construction supplies Diffraction gradients Worksheets

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Sounds of the Sun	Students will be able to explain the Doppler effect and the relationship between speed and direction of source, and frequency of sound waves. Students will be able to explain how the Doppler shift can be used to gather information about objects in space including the Sun. Students will be able to calculate the change in frequency of sound emitted by a moving object using the Doppler equations.	When a source emitting waves, sound or light, is moving, the frequency of those waves changes. When the source is moving towards the observer, the frequency increases. When it is moving away, it decreases. With sound this is observed as a change in pitch, with light the spectrum is shifted. The faster the motion, the greater the shift. This can be used by astronomers to measure the speed and distance of objects in space. SDO's HMI instrument uses it to find waves on the surface of the Sun, and track their motion.	Frequency Wave Source Doppler Effect	Students begin by simulating the noise made by a passing siren. After learning that the change in pitch results from movement they investigate the definition of frequency. Students conclude by calculating the change in frequency heard when they simulated the noise of the passing siren, and learn how this applies to light and the study of astronomy.	Doppler ball Meter Stick Calculators Ramp, 4ft long. Small balls (malted milk balls or marbles)

Pre and Post Assessment

Name:____ Date:__________

Read the question completely before answering. Answer all questions using complete sentences. For multiple choice questions choose the best answer.

1. What is the Sun?

2. Describe the size of the Sun compared to the size of Earth:

3. Describe the shape of Earth's orbit.

4. When is Earth closest to the Sun?
   a. June
   b. December
   c. March
   d. September

5. What is the difference between *direct* and *indirect* light?

6. When a part of earth receives more hours of daylight, how does that affect temperature at that location?

7. What causes seasons on earth? How does this cause seasons? (Answer both parts of this question.)

8. Define *Solstice* and *Equinox*:
   a. Solstice is…

   b. Equinox is…

9. How does a sundial work?

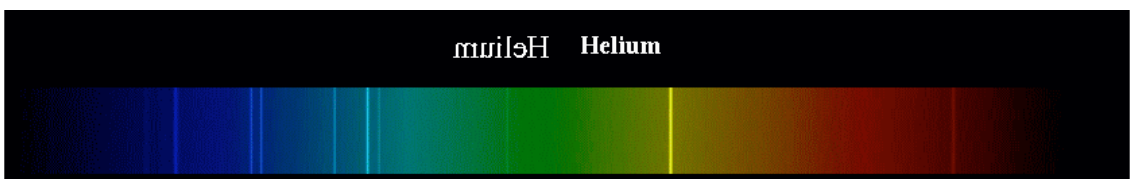
10. What is a Sunspot?

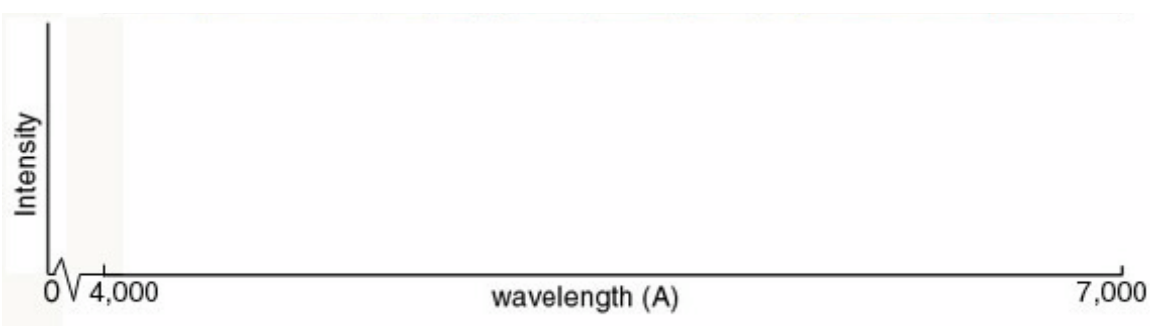
11. How can we see the magnetic field on the Sun?

12. List four (4) kinds of energy in the electromagnetic spectrum:

13. Convert 10^{-2} into a fraction, and a decimal:

14. Graph the spectra below:





15. What is the Doppler Effect?

16. How are the *velocity* of a source and the *wavelength* and *frequency* it emits related?

The Size of the Sun

Grades:
5 - 8

Objectives:

- Students will be able to use a pinhole camera to calculate the Sun's diameter.
- Students will be able to calculate a scale model using the distance between Earth and the Sun.

Description:

Students will construct a pinhole camera. Using the projected image of the Sun they can calculate its diameter. After calculating the diameter of the Sun, students will create a classroom sized scale model of the Sun and Earth.

Suggested Timing:
25 – 30 minutes.

National Standards
Content Standard D: As a result of their activities in grades 5 – 8, all students should develop an understanding of Earth in the solar system, 1: The Sun, an average star, is the central and largest body in the solar system.

Vocabulary:

- Diameter
- Ratio
- Scale
- Model

Materials: (One per group)

- One pin
- Two index cards
- One shoe box with lid – sturdy enough to hold it' shape.
- Tape
- Aluminum foil
- Ruler
- Meter stick
- Calculator

Background Information:

The Sun is the largest body in our solar system, accounting for more than 99% of its mass. Pinhole cameras are a safe way to observe the Sun. Most optical devices rely on refraction or reflection to provide an image on a screen or film plane. A pinhole camera is a device that does not use lenses or mirrors to produce its image, but rather only a small circular aperture, or ‘pinhole’. This apparent lack of imaging optics does not mean that such an arrangement of hole and screen cannot produce an image. It does and with the greatest detail. What it looses when comparing it to other optical instruments is its light gathering capabilities due to the relatively small aperture to screen distance ratio, i.e. the inverse square law. The issue with a pinhole camera is that the sharpness of the image requires a small aperture relative to the screen distance – which means less light gathering power.

However, even with this shortcoming it still is a candidate for observing the sky’s brightest object, the Sun.

If a screen is placed a small distance behind a small aperture where a bright object, in this case the Sun, is on the other side of the aperture, an image of the object will be produced by the light rays passing from the object straight through the ‘pinhole’ and onto the screen. However, if the screen is too close to the hole, no image will result since some distance is required for an image to be formed. If the screen is placed too far from the hole then diffraction effects (interference phenomena of the light photons due to there inherent wave nature) will come into play degrading the image. Therefore, there must be some optimum distance from the pinhole to the screen at which the image produced will be clearest, i.e. maximum resolution. These measurements can be found in Table I.

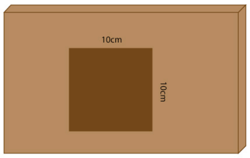
Table I

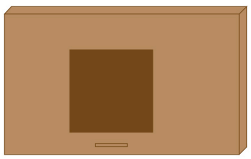
Pinhole Diameter in mm	Screen Distance in M	Solar Image Diameter in cm	Relative Resolution
1	0.745	0.69	6.9
2	2.98	2.8	14.0
3	6.2	6.2	20.6
4	11.9	11.1	27.8
8	47.7	44.4	55.5
16	190.	177.	111.
32	760.	707.	221.

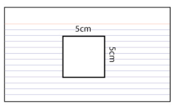
(Credit: http://users.erols.com/njastro/barry/pages/pinhole.htm, 2009)

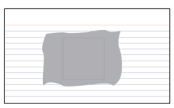
The Sun’s diameter can be calculated using the ratio of Earth’s size and distance to that of the Sun. A scale model can then be calculated.

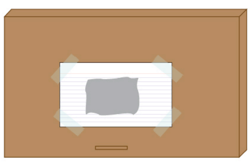
Content:

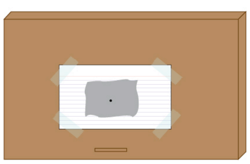
1. 

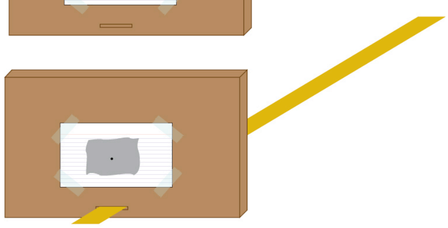
2. 

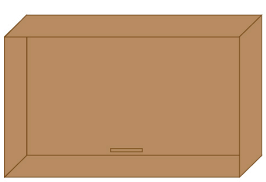
3. 

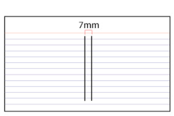
4. 

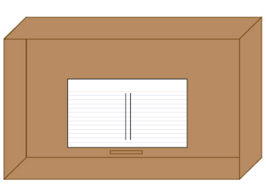
5. 

6. 

7. 

8. 

9. 

10. 

Predict: (Engagement and assessing prior knowledge)

Ask: How big is the Sun? Is there a way to measure its size?
Give students a few minutes to brainstorm.
Probing question ideas: Can we see the Sun? Is there a way to measure something at a distance? Does it matter how far away you are? What is a ratio?

Explain to students that they will be using a pinhole camera to measure and calculate the diameter of the Sun.

Method: (Body of the lesson)
Assemble the Pinhole Viewer:

1. Take the lid of the shoe box and cut a 10cm x 10cm square hole in the center.

2. Cut an "I" shaped slit lengthwise on the top of the lid 1cm from one edge. This will be the "bottom" edge of the lid. Make the slit long enough to snugly fit a meter stick.

3. Take an index card and cut a 5cm x 5cm square hole in the center.

4. Tape a piece of aluminum foil over the hole in the index card.

5. Tape the index card over the hole in the lid of the shoe box. This creates an easily replaceable pinhole should the foil rip. Several of these cards can be made for each pinhole camera.

6. Using a pin or pencil lead poke a very small hole in the center of the aluminum foil. If you tear the foil replace it and try making the hole again.

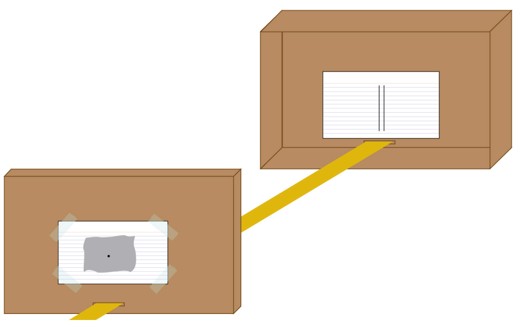
7. Slide the meter stick through the slit and tape the lid in place at the end of the meter stick.

8. Cut and "I" shaped slit lengthwise on the bottom of the shoe box 1cm from one edge. This will be the "bottom" edge of the shoe box. Make the slit long enough to snugly fit a meter stick.

9. Draw two parallel lines 7mm apart near the center of the second index card.

10. Tape the index card to the center of the bottom of the inside of the shoe box.

11. Slide the free end of the meter stick through the slot in the shoe box so that the open side faces the lid. Leave this end of the box free to slide up and down the meter stick. Use a small piece of masking tape to hold it in place when needed.



Take the pinhole viewer outside and point the end of the meter stick that holds the foil-covered card toward the Sun.

CAUTION: Do not look at the Sun!

Move the meter stick around until the shadow of the foil-covered card falls on the other card. A bright image of the Sun will appear on the sliding card.

Move the sliding card until the bright image of the Sun exactly fills the distance between the parallel lines.

Measure the distance in mm between the cards on the meter stick and record it.

Bring students back inside and give them this formula to calculate the distance to the Sun:

Earth is approximately 150,000,000 km from the Sun. This distance varies somewhat with the seasons because of Earth's elliptical orbit.

The relationship that will be used is:

$$\frac{\text{diameter of Sun (km)}}{\text{distance to Sun (km)}} = \frac{\text{diameter of Sun's image (mm)}}{\text{distance between cards (mm)}}$$

Live-It: (Assessment/application assignment)

Once students have calculated the diameter of the Sun, explain that they will now be calculating a classroom sized scale model of the Sun and Earth.

Creating the model:

1. Choose a scale for the model. A good size is 10,000 km = 1 cm.
2. Calculate how big the Sun would be at that scale. (Size of the Sun divided by the scale (10,000km) = diameter of the Sun in cm)
3. Repeat for Earth, and the distance between Earth and the Sun.
4. Measure and cut out model Sun and earth of the appropriate size.
5. Pace off the correct distance between the Sun and Earth. This activity may need to go outside to have enough room.

Have students answer these questions:

Was this model what you expected?
How was it different?
Is Earth always the same distance from the Sun?

Extension:

The actual distance between Earth and Sun varies from a minimum of 147,097,000 km to a maximum of 152,086,000 km. Recalculate the diameter of the Sun using your distance between cards measurement and the minimum/maximum distance between Earth and Sun in the formula.

Does the accepted actual diameter of the Sun, 1,391,000, fall between your calculations?

Resources:

Pinhole viewers explained:
http://users.erols.com/njastro/barry/pages/pinhole.htm

NOTES:

Earth's Orbit

* This activity is from the Great Explorations in Math and Science (GEMS) teacher's guide The Real Reasons for Seasons, copyright by The Regents of the University of California and used here with permission. GEMS is a program of the Lawrence Hall of Science at the University of California, Berkeley (www.lhsgems.org)

Grades:
5 - 8

Objectives:
- Students will be able to define foci and ellipse.
- Student will be able to define earth's orbit as an ellipse.
- Students will be able to explain that Earth is closest to the Sun in December, and farthest away from the Sun in June.

Description:
Students draw a circle with a single focus, an ellipse with two foci close together, and an ellipse with two foci far apart. They compare the shapes. Students measure the Sun in four images each taken in a different season, comparing the apparent size of the Sun in each image to determine when Earth is closest to the Sun.

Suggested Timing:
25 – 30 minutes.

National Standards
Content Standard D: As a result of their activities in grades 5 – 8, all students should develop an understanding of Earth in the solar system, 1: The Sun, an average star, is the central and largest body in the solar system.

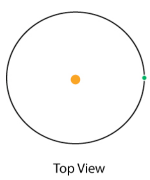
Vocabulary:
- Ellipse
- Focus
- Foci
- Apparent
- Actual

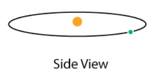
Materials: (One per group)

- 25 cm length of string tied in a loop.
- Two thumb tacks (the tall kind, not the flush kind)
- Square of corrugated cardboard.
- Paper
- Telescope images of the Sun in each season.
- Ruler
- 40 cm of string tied in a loop for teacher demo.
- 1 large sheet of paper (legal size or larger)

Background Information:

The shape of earth's orbit around the Sun is a common misconception. Most textbook illustrations show a highly elliptical shape, attempting to illustrate the Sun/earth system from an angle.





In actuality, Earth's orbit around the Sun is an ellipse. An ellipse is a shape with two foci (focus, singular, foci, plural). Earth's orbit is an ellipse whose foci are so close together, they are both inside the Sun. The closer together the foci, the more similar the ellipse is to a circle. Earth's orbit brings it closest to the Sun in January, with a difference of only 5 million miles. This distance is not enough to influence changing seasons here on earth, and does not explain opposing seasons in opposite hemispheres.

Content:

Predict: (Engagement and assessing prior knowledge)

Ask students to guess what month Earth is closest to the Sun, and to explain their answer. Possible responses include: June, July, August – Because that's when we are the hottest. Question students about their belief that Earth's distance to the Sun affects seasons.

Ask: How could we test and see when we are closest to the Sun? How do you know when you are closer to something? Question students until they conclude that when an object is closer, it appears larger.

Explain that students will be given four images of the Sun in four different seasons, and they are to measure its diameter. Students must be very careful in choosing where to measure the images, making sure to begin and end on the same boundary in each image. Pass out the images of Sun and rulers. Have them record their measurements.

Have students write their measurements on the board for the class to see. Discuss what their numbers mean. Does distance to the Sun affect seasons? The answer is no, because Earth is actually closest to the Sun in January. The topic of summer being in January in the southern hemisphere may come up, while this activity may not have the same impact for southern hemisphere classrooms, ask students why only half of Earth would be summer if the whole earth was closer to the Sun?

Method: (Body of the lesson)

Ask students to draw how they think Earth's orbit around the Sun is shaped. Question students as to why they chose the shape they did. Where have they seen it before? Explain that they are going to be learning about that shape and what it has to do with seasons on earth.

Explain that the shape of earth's orbit is an ellipse, a very precise symmetrical oval. Demonstrate making an ellipse:

1. Make two pen marks 12 cm apart on a large sheet of paper on the bulletin board.
2. Stick a thumb tack through each pen mark and into the bulletin board.
3. Drape the large 40 cm of string loop you made over the thumb tacks.
4. Pull the string taut with the tip of a marking pen.
5. Draw the ellipse, keeping the string taut at all times.

Explain that each point where you placed a tack is called a *focus*. Mention that the plural of focus is *foci* (FOE-sigh). Explain that objects in the solar system orbit around the Sun, but that the Sun is only one focus of the ellipse. Tell students that their assignment is to draw an ellipse using 25 cm length of string tied in a loop, and to experiment with the distance between the foci.

Live-It: (Assessment/application assignment)

Instruct students to draw three ellipses with foci separations of 5cm, 2cm and 0.4cm respectively on a single sheet of paper. Remind them to label the ellipses and suggest using different color pencils. Hand out materials and assist student groups as needed.

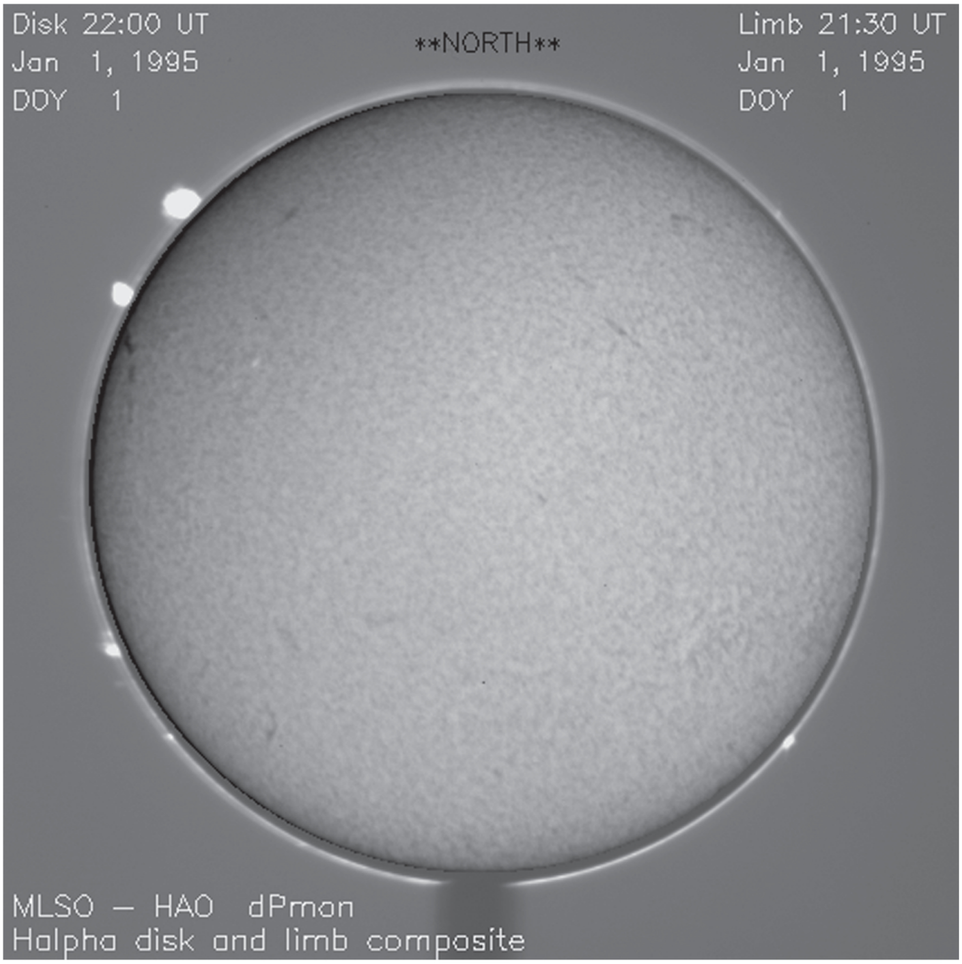
When each group is done ask students what happened to the ellipse when they moved the foci closer together? Tell students that one ellipse is the orbit of Pluto, and another one is the orbit of Earth. Ask them to guess which one is which, then reveal that Pluto's orbit is the shape with 5cm of separation between foci, and earth's orbit is the shape with 0.4cm of separation between foci. Tell them that the foci of Earth's orbit in space are so close together they are both inside the Sun, and that earth's orbit is very nearly a perfect circle.

Extension:

Have students explore the orbits of other planets. Students who research Pluto will find that from 1979 to 1999 Pluto was closer to the Sun than Neptune, making it at the time the 8th planet. The highly elliptical nature of Pluto's orbit meant that it crossed Neptune's orbit at one point, making Neptune the dominant body in it's orbit. This was one factor in Pluto being demoted to planetoid status in August 2006.

Resources:
The Nine Planets
http://nineplanets.org/

The Solar System, NASA
http://solarsystem.nasa.gov/index.cfm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DOY 1
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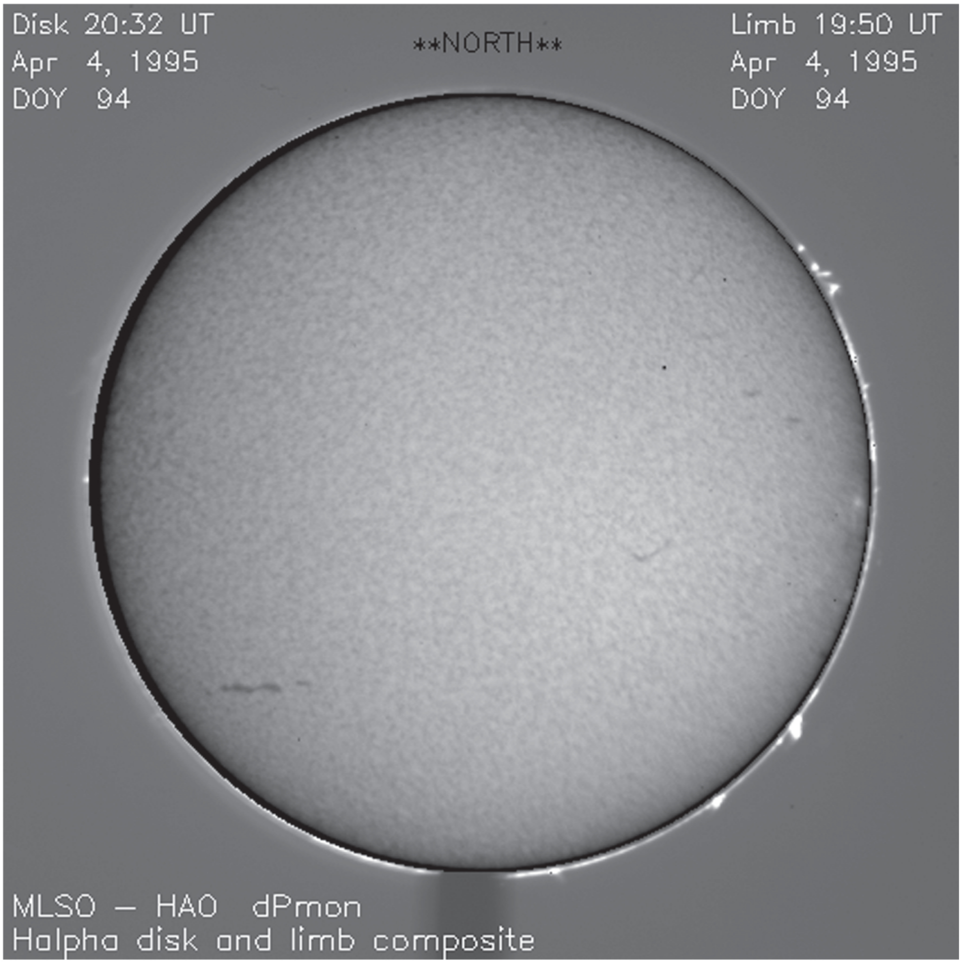
Halpha disk and limb composite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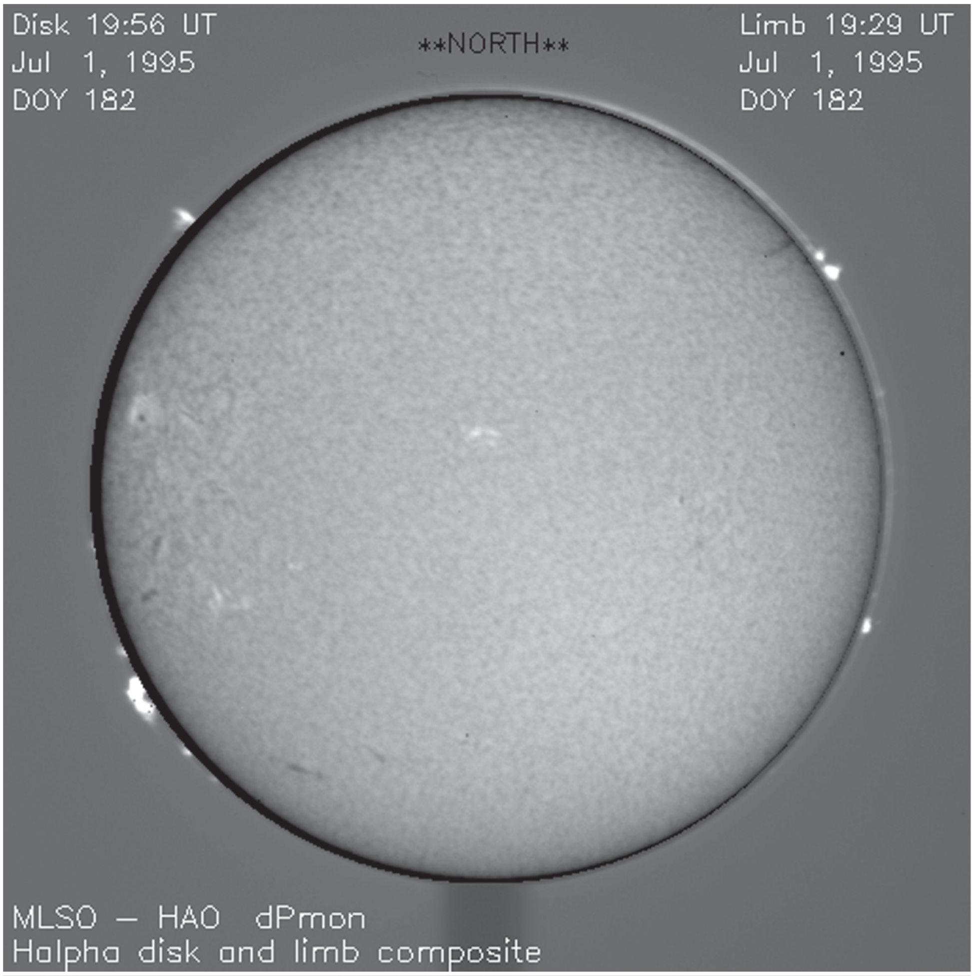
Halpha disk and limb composite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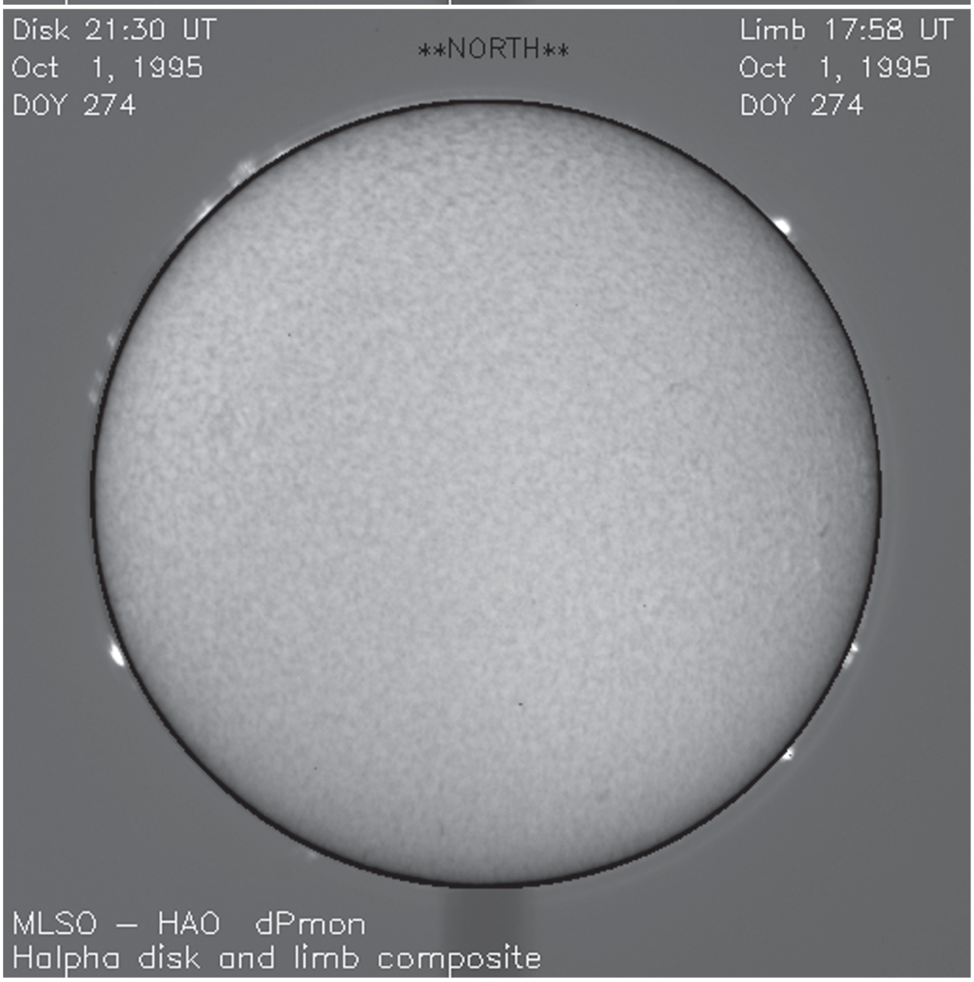
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DOY 274
NORTH
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Oct 1, 1995
DOY 274
MLSO – HAO dPmon
Halpha disk and limb composite

Light, Directly

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Grades:
5 - 8

Objectives:

- Students will be able to explain that direct Sunlight transfers more energy to an area than indirect Sunlight.
- Students will be able to explain that light hitting Earth perpendicularly is considered “direct” light, and light hitting Earth at a low angle is considered “indirect” light.

Description:
Students review Earth’s position relative to the Sun. Students then use graph paper to investigate the effect of angle on area illuminated. The fraction of “light” on each square is then calculated and compared.

Suggested Timing:
25 – 30 minutes.

National Standards
Content Standard D: As a result of their activities in grades 5 – 8, all students should develop an understanding of Earth in the solar system, 4: Seasons result from the variations in the amount of the Sun’s energy hitting the surface, due to the tilt of Earth’s rotation on it’s axle and the length of day.

Vocabulary:

- Direct
- Indirect
- Percentage
- Fraction
- Energy

Materials:

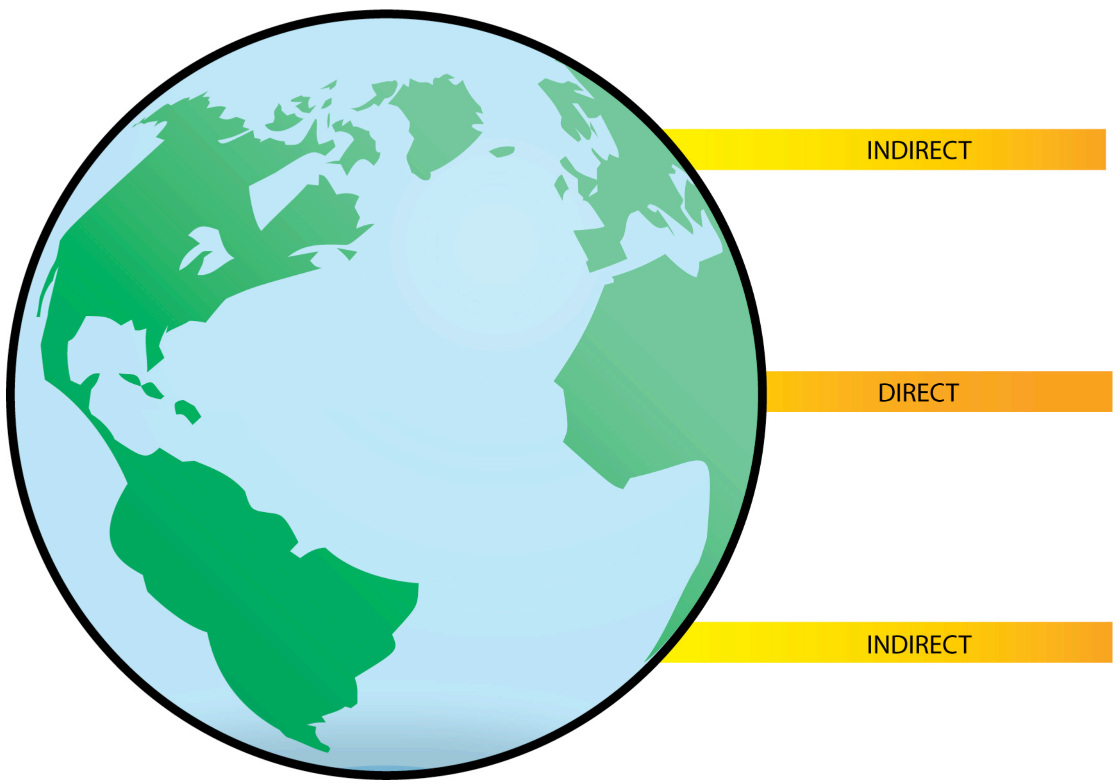
- Light bulb and power source
- Globe

For each student:

- Scissors
- Brad fastener
- Sun Angle Analyzer printed on cardstock

Background Information:

The energy received on any portion of Earth is a fraction of the total energy that comes from the Sun. Because Earth is a sphere, areas tilted away from the Sun receive indirect Sunlight, Sunlight that has been spread out over a larger surface area. Areas directly facing the Sun receive direct Sunlight – more energy from the Sun and because of that, are warmer.

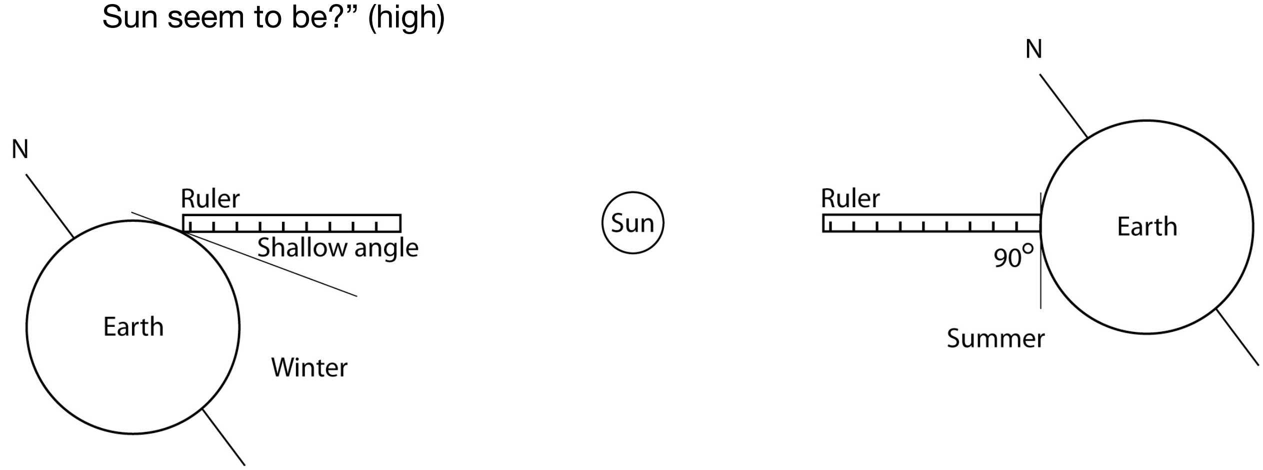


Content:

Predict: (Engagement and assessing prior knowledge)

The Angle of Sunlight

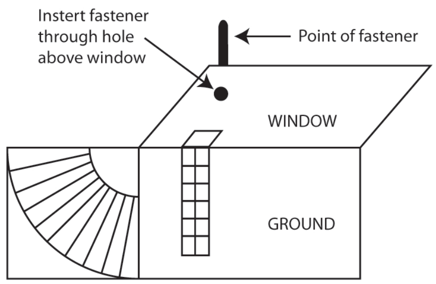
1. Tell the class that they already understand more about the seasons than many college graduates, but there is one more issue they need to consider before they can be considered experts on seasons. Explain that now they are going to look more carefully at how high the Sun appears in the sky during different seasons.
2. Turn on the light bulb-model Sun or use a point on the chalkboard or wall to represent the Sun. Hold up the class globe, and point out your location in the Northern Hemisphere. Tilt the Northern Hemisphere towards the Sun. Review, “What season is it where we live?” (summer) Spin the globe so your location is facing the Sun. “What time is it?” (noon)
3. Keep Earth in the summer noon position for your location.
4. Hold up a ruler. Say that it represents a ray of Sunlight coming from the Sun to Earth during our summertime. Explain that light travels in a straight line. Place one end of the ruler on your location, and point the other end toward the Sun. (The ruler should hit the globe at a nearly perpendicular angle, as in the right-hand side of the drawing below.) Ask, “To someone at this point on Earth, would the Sun appear high in the sky or low in the sky?”
5. Ask how Earth is tilted when it’s winter. Walk to the other side of the Sun and tilt the Northern Hemisphere away from the Sun, but spin it so your location is facing the Sun. Point out that the angle at which the ruler “Sunlight ray” strikes the globe is now at a very shallow angle. (As in the left-hand side of the above drawing.)
6. Help students see that the Sun would seem to be overhead in the summer, but lower in the sky in winter. For each position, ask, “Where in the sky does the Sun seem to be?” (high)



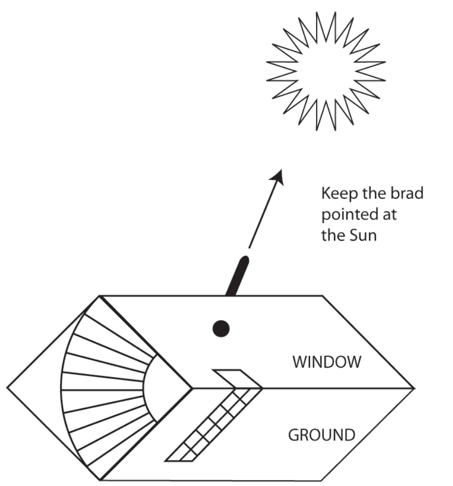
Method: (Body of the lesson)

Introducing the Sun Angle Analyzer

1. Tell the students that they get to use a “Sun Angle Analyzer” to see what happens when light hits the ground at different angles.

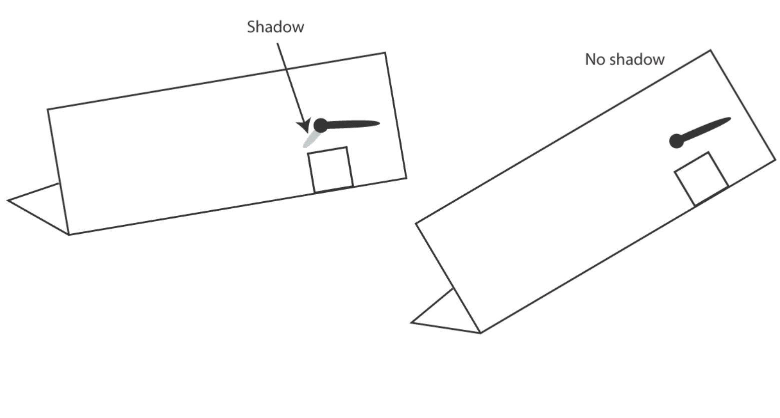


2. Demonstrate how to stick a paper fastener (brad) through the “x” mark just above the “window” hole. Poke it through from the printed side of the paper, so that the point sticks out on the blank side of the paper. Tape the head of the fastener down on the x to help keep it perpendicular to the window. Tell students not to open the two prongs of the fastener, but to leave them closed. The fastener prongs will serve as a “pointer.”

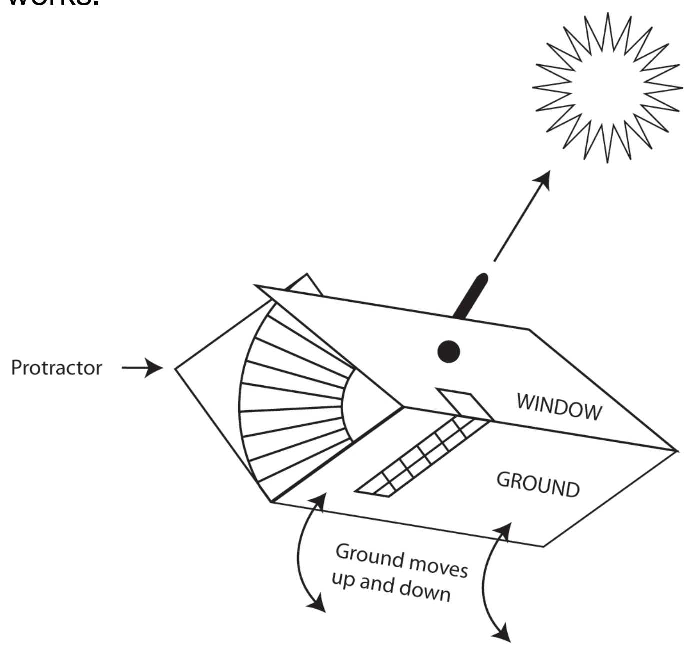


3. Explain that they’ll use the analyzer with a partner. Hand out a Sun Angle Analyzer and a fastener to each pair of students. Once they have their fasteners in place, have them all gather around the light bulb. Turn off the room lights and close the blinds if possible.

4. Ignoring the protractor part for now, practice using the analyzers together. Call their attention to the instructions written on the Sun Angle Analyzers.
   a. Partner #1 holds the window portion of the Analyzer and keeps it so that the standard, one-square-centimeter window area stays perpendicular to the light rays. If the Window is allowed to stray significantly away from perpendicular, the area of light going through the window will no longer be the standard 1 square centimeter.



5. The brad helps since, when the brad points directly to the light bulb, it does not cast a shadow. If the brad casts a shadow, you need to tilt the analyzer a bit until there is no shadow, making the standard, one-square-centimeter area window again perpendicular to the light rays. Give students time to play with the analyzers to see how this works.
    a. Partner #2 moves the “ground” up and down. Explain that the part of the analyzer with the grid on it represents the ground. Ignoring the protractor for the moment, have the second partner practice moving the ground up and down, while partner #1 tries to keep the analyzer aligned with the light bulb. Give students time to play with the Analyzers to see how this works.



6. Note: It is important for students to understand that, in this model, the ground really does represent the ground of Earth— changing the position of the ground represents the way Earth’s position actually does change in relation to the Sunlight, due to Earth’s tilt. That is why students should move the ground up and down, rather than the window.
    a. Try not to block the light. Both partners should try to avoid standing so that they block the light to their Analyzer or someone else’s. Circulate and help any students who are having trouble.

7. Regain the attention of the whole group, and ask what they have noticed. (As the ground moves up closer to the window, fewer grid squares are covered by light. Students may also notice that the light seems brighter when fewer squares are covered with light.)

8. Tell students the protractor scale is for measuring the angle of the light hitting the ground. Demonstrate how to read the angle as they push the ground up.

Ask, “What angle does the protractor read when the ground is pushed all the way up to the window?” [90 degrees.] Tell them this means that the light rays are hitting the ground at 90 degrees. Another way to say that is that the light is coming down perpendicular to the ground. Show the 90 degree angle by making a T- shape with your hands.

9. Tell the students that their job is to find the angle of the light when:
    - The light spreads over 4 grid squares
    - The light spreads over 6 grid squares
    - The light spreads over all grid squares

Live-It: (Assessment/application assignment)

Discussing the Sun Angle Analyzer Results

1. Ask for the angle of light when only four grid squares were filled with light. [90°]
2. Ask for the light angle when six grid squares were filled with light. (Answers may vary) What about when all grid squares were filled? (Small angle) Acknowledge that variation in answers may be due to imprecision of the instrument and inaccuracies in measurement.
3. Ask if students noticed any changes in how bright the light looked. Ask, “At which angle is the light most concentrated, or brightest looking on the ‘ground’?” (at the highest angle: 90°) “At which angle is the light least concentrated (least bright) on the ‘ground’?” (at the lower angles. At 0° light concentration vanishes!)
4. Tell students that when the light is more concentrated, the ground gets hotter. Help them relate their discoveries with the light analyzers to Earth’s seasons. (In summer, the angle of Sunlight hitting the ground is higher. The light is more concentrated, so the ground gets hotter.)

Extension:

Have students consider the amount of squares illuminated as a fraction of the whole, and calculate what fraction of light is on each square at 10 degree increments. For example:

> At X angle, 4 squares are illuminated, each square has ¼ the energy of the total available amount of energy.

Resources:

Calculate the angle of the Sun in your sky:
http://susdesign.com/Sunangle/

Sun angle animation:
http://cwx.prenhall.com/bookbind/pubbooks/lutgens3/medialib/earthSun/earthSun.html

Sun Angle Analyzer

Insert brad here
Keep brad pointing at the "Sun"

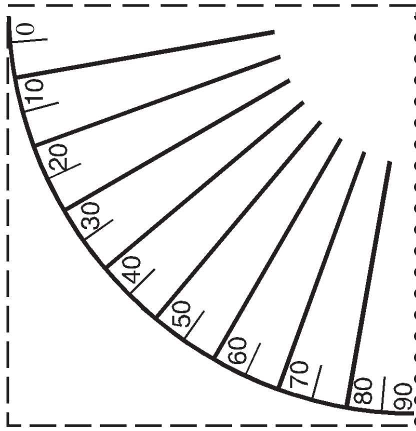
Fixed Window

Keep this perpendicular to the light rays to create 1 cm square standard area of light.

Cut out this window

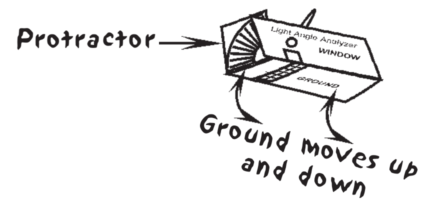
Fold

Fold



GROUND

Move this part up and down to see the effect of angle of light on the ground.



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Lawrence Hall of Science
University of California

Sun Angle Analyzer

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Keep brad pointing at the "Sun"

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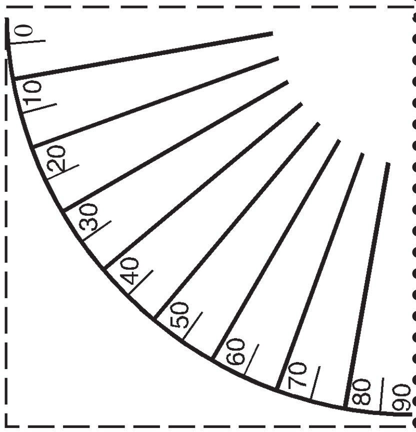
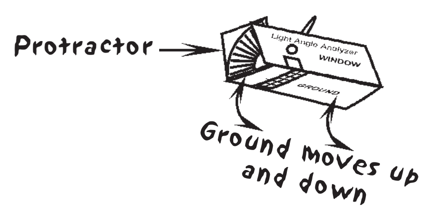
Fold

Fold



GROUND

Move this part up and down to see the effect of angle of light on the ground.



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Graphing the Globe

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Grades:
5 - 8

Objectives:

- Students will be able to explain that day length and temperature are related.
- Students will be able to create and analyze a graph.

Description:

The class is split into two different teams, groups on the first team graph hours of Sunlight versus month for a number of latitudes. The second group graphs temperature versus month for the same latitudes. Teams compare data and draw conclusions from their analysis.

Suggested Timing:
30 – 45 minutes.

National Standards
Content Standard D: As a result of their activities in grades 5 – 8, all students should develop an understanding of Earth in the solar system, 4: Seasons result from the variations in the amount of the Sun's energy hitting the surface, due to the tilt of Earth's rotation on it's axle and the length of day.

Vocabulary:

- Minimum
- Maximum
- Analyze
- Correlate
- Conclude

Materials: (One per group)

- Data sets
- Graph handouts.
- Colored pencils.
- Blank graph transparency

Background Information:

The length of day varies with latitude and with time of year. By graphing the hours of daylight over the course of a year in various locations, a symmetric pattern emerges showing opposite for the northern and southern hemispheres. During the months when the Sun does not set in Antarctica, the Sun never rises in places north of the Arctic Circle. The solstice and equinox can be observed in the graph as well. All lines intersect at the vernal and autumnal equinox, and diverge at maximum at the solstices. The tilt of Earth causes the northern hemisphere to receive the most Sunlight in June, resulting in higher temperatures. A similar pattern emerges when temperature versus month are plotted. Other factors affect weather, like proximity to water and elevation, so the pattern does not identically correlate to the graph of hours of daylight, but they are similar enough to compare.

Content:

Predict: (Engagement and assessing prior knowledge)

To review their experience with changes in the number of daylight hours, ask the following questions:

Does the Sun always set at the same time each day? [No] Optional: show a photograph of a Sunset to add a vivid element to this discussion.

At what times of year does the Sun stay up latest (and rise the earliest)?
[Summer. Don't reveal the answer if no one knows.]

Is the number of hours of daylight the same each day? [No]

When are the days with the fewest hours of daylight? [Winter]

Ask, "Is the number of hours of daylight on a certain day the same all over the world?" Tell the students that in this session, they will look at day length data from different places around the world.

Method: (Body of the lesson)

Graphing Daylight:

1. Show the sample “Day Length” data for Latitude 38 degrees north on the overhead projector. Explain what each column means: Sunrise time, Sunset time, and “Day Length,” which is the number of actual hours of daylight on the 21st day of each month. Show on a world map or globe how all the cities in this list are on the same latitude, 38 degrees north.
2. Explain that this data are on the worksheet, along with data for seven other latitudes, with some cities listed for each. Model how to graph the day length for one of the latitudes on a blank graph transparency.
3. Assign the students to graph as many of the “Day Length” values from the eight latitudes as they can fit on the graphs. Have them color code the plot lines with a different color for each latitude.
4. Tell them that the first two latitudes they plot should be in opposite hemispheres: one in the Southern Hemisphere and one in the Northern Hemisphere. For students who are not as proficient at graphing, you might hint that a latitude near 0° (e.g., Ecuador) might be a particularly easy place to start.
5. Allow the students to continue graphing as long as possible, but leave at least ten minutes for a discussion. Try to be sure all students have finished graphing at least three or four of the eight latitudes before the discussion.

Graphing Temperatures Around the World:

1. Tell the class that they will look at the temperature during the year in nine different places on Earth. Hand out the data sheets and graph papers.
2. Explain (or remind them) that scientists all over the world use the Celsius temperature scale. If students are used to the Fahrenheit scale, you may want to refresh their memory on the relationship between the two scales.
3. Put the blank Temperature Graph transparency on the overhead projector. Demonstrate how to plot, for instance, a temperature average of 12°C in January. Point out that the lines on the graph are two degrees apart. Make sure students know what negative numbers mean, and how to plot temperatures that are below zero.
4. Ask, “What do you think the graph would look like in our area over the time period from January to June?” (Average temperature will rise.) “What would happen after that?” (Average temperature will fall.)
5. Ask, “Does the temperature have the same pattern as ours all over the world?” Explain that by graphing temperatures from several places around the world, they can find out if seasons differ in various locations.
6. If your students need practice, plot the average temperatures for Chalatenango, El Salvador together on the overhead transparency. Then assign the students to plot average temperatures for as many cities as they can on the “Temperatures Around the World” graph. It’s not necessary for each student to graph all temperatures in all locations, though some really get into the process and gain a sense of great satisfaction when the whole job is done. It works well if the first

two cities they plot are in opposite hemispheres - one in the Northern Hemisphere and one in the Southern Hemisphere. Here are a few different strategies to choose from.

a. Have each student graph three cities: one Northern Hemisphere, on Southern Hemisphere, and one near the equator.
b. Have each small group of students practice “division of labor,” with each student taking two different cities to graph, but not necessarily the same ones as others in their group, so that by working together the group has a complete set of graphs.
c. Assign various groups of students to pretend they are from the different cities. They start by graphing their own city’s data and then move on to other cities. If they like, they can decide on their own strategy like moving to the closest cities first, or working their way north or south.
d. Allow students to do more graphing at home for extra credit, or just for the sheer satisfaction of “job completion.

7. Tell students to connect the data points with a smooth line. If data are missing for any months, they should estimate where the plot line would go for those months. After plotting in pencil, they should trace over each line with a different color. Have them make a key by writing the color used, country name, and latitude on the right side of the graph. If they run out of colored pens, they can connect points with dashed or dotted lines, as a coding scheme. In some cases, the months do not run from January to December, but for example, from July of one year to June of the next. Tell students not to worry about which year the month is in. Just be careful to plot the right average temperature to the right month of the year on the graph.

Live-It: (Assessment/application assignment)

1. After all students have plotted at least three cities on each of the graphs, gather their attention, and ask, “What have we found out? ” “What patterns do you see in your graphs?”
2. Make sure students notice that the pattern is reversed between the Northern and Southern Hemispheres.
3. Ask, “What is the pattern of temperature change for locations near the equator?” There is not much variation in temperature through all the seasons.
4. “Where and when does the Sun stay up for 24 hours?” The Sun never sets from May through July above 70°N latitude (Alaska); also
5. November through January at latitudes south of 70° S. (Antarctica) This is sometimes called the “midnight Sun.”
6. If no one points out that all the lines converge at two points, ask, “Are there any places where all the lines come together?” Yes, in March and September. “What seasons are in March and September?” Spring and fall, respectively.
7. Explain that there is a special name for the exact date where all the lines come together, when the number of hours of daylight equals the number of hours of

nighttime. Ask if anyone knows what those special days are called. Equinoxes—Spring equinox and fall or autumnal equinox. They occur near March 21 and September 21 each year.

Extension:

Have students research the rotation axis of Mars and determine how it is similar to that of earth in terms of tilt. Answer the following questions:

Are the northern and southern hemispheres of Mars similar to the northern and southern hemisphere of Earth? How are they similar? How are they different? How long is one year on Mars? How long is one day on Mars?

Resources:

Pulse of the planet animation:
http://svs.gsfc.nasa.gov/goto?2395

World Climate:
http://www.worldclimate.com/

Learn about Mars:
http://marsprogram.jpl.nasa.gov/funzone_flash.html

5. Temperatures Around the World

Average Temperatures: 1996-1998 Data from GLOBE Schools Around the World

Data is in Degrees Celsius (°C)

Below are Celsius to Fahrenheit Temperature Conversions

°C	°F
-40	-40.0
-18	-0.4
-16	3.2
-14	6.8
-12	10.4
-10	14.0
-8	17.6
-6	21.2
-4	24.8
-2	28.4
0	32.0
2	35.6
4	39.2
6	42.8
8	46.4
10	50.0
12	53.6
14	57.2
16	60.8
18	64.4
20	68.0
22	71.6
24	75.2
26	78.8
28	82.4
30	86.0
32	89.6
34	93.2
36	96.8
38	100.4
40	104.0
100	212.0

°F = (°C x 9/5) + 32

Escuela Antarctica, Esperanza;
Provincial #38 Julio Argentina Roca
Latitude: 63°S
Longitude: 57°W
Elevation: 10 m

Month	Year	Avg Temp
May	1998	-3.9
Jun	1998	-4.2
Jul	1998	-12.5
Aug	1998	-11.5
Apr	1998	3.8
Sep	1998	-9.7
Oct	1998	-6.3
Nov	1998	0.6
Dec	1998	1.2

Quito, Ecuador;
Colegio Albert Einstein
Lat:0°N Long:78°W
Elevation: 2890 m

Month	Year	Avg Temp
Jan	1998	18.8
Feb	1998	18.4
Mar	1998	17.6
Apr	1998	16.0
May	1998	19.7
Jun	1998	17.1
{Aug	1997	17.6}
{Sep	1997	18.4}
{Oct	1997	18.0}
Nov	1997	18.3
Dec	1997	16.7

Kyoto, Japan
Koryu JrHS
Latitude: 36°N
Longitude: 135° E
Elevation: 8 m

Month	Year	Avg Temp
Jan	1996	4.4
Feb	1996	2.9
Mar	1996	6.9
Apr	1996	9.5
May	1996	16.4
Jun	1996	21.2
Jul	1996	24.3
Aug	1996	25.5
Sep	1996	20.2
Oct	1996	15.7
Nov	1995	10.3
Dec	1995	5.8

Sandy Bay,Australia
Fahan School
Latitude: 43°S
Longitude: 147°E
Elevation: 20 m

Month	Year	Avg Temp
{Jan	1998	18.0}
Feb	1998	17.5
Mar	1998	17.9
Apr	1998	14.7
May	1998	12.8
Jun	1998	10.1
Jul	1998	11.0
Aug	1998	10.6
Sep	1998	15.2
Oct	1998	13.7
Nov	1998	14.6

Chalatenango, El Salvador;
Escuela Rural Mixta
Latitude: 14°N
Longitude: 89°W
Elevation: 1700 m

Month	Year	Avg Temp
Feb	1997	15.4
Mar	1997	15.5
Apr	1997	15.3
May	1997	16.0
Jun	1997	15.7
Jul	1997	15.7
Aug	1997	16.3
Sep	1997	16.5
Oct	1997	16.9
Dec	1996	15.1

Minnesota USA
Detroit Lakes Middle School
Lat:47°N Long:96°W
Elevation: 1431 m

Month	Year	Avg Temp
Jan	1997	-14.1
Feb	1997	-9.2
Mar	1997	-2.1
Apr	1997	2.8
May	1997	10.6
Jun	1997	20.3
Jul	1997	19.3
Aug	1997	18.9
Sep	1997	17.3
Oct	1997	3.8
Nov	1997	-5.5
Dec	1997	-4.5

Carltonville, S Africa;
Tsitsiboga Primary School
Lat:26°S Long:27°E
Elevation : 1524 m

Month	Year	Avg Temp
Feb	1998	20.8
Mar	1998	25.2
Apr	1998	23.5
May	1998	18.9
Jun	1998	11.8
Jul	1998	13.9
Sep	1998	14.8
Oct	1998	18.8
Nov	1998	19.1

Guangzhou, China
Guangdong Guangya MS
Latitude: 23°N
Longitude: 113°E
Elevation: 20 m

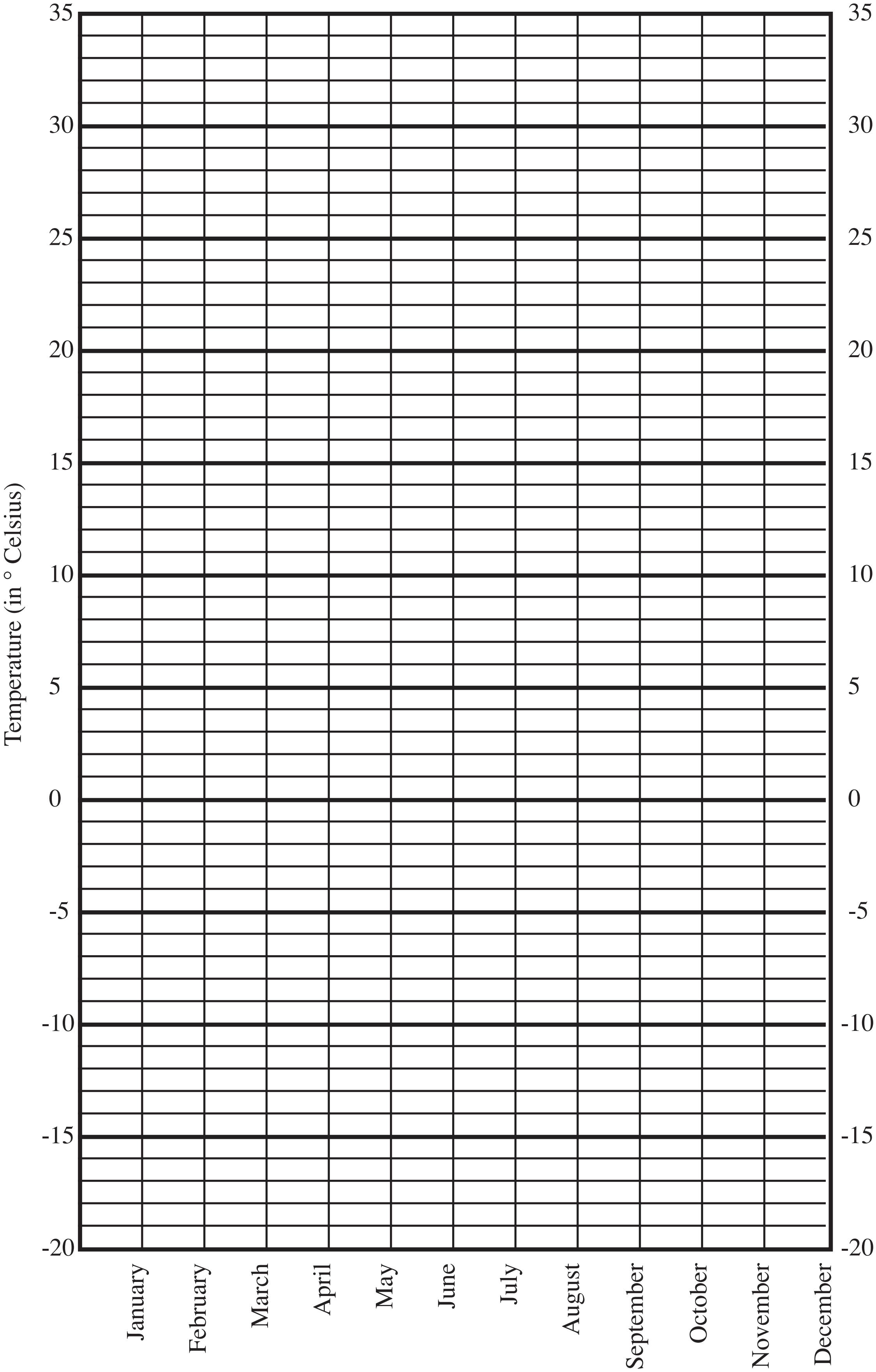
Month	Year	Avg Temp
Jan	1999	13.7
Feb	1998	18.4
Mar	1998	18.5
Apr	1998	23.6
May	1998	24.8
Jun	1998	27.2
Jul-Aug	{no data}	
Sep	1998	27.2
Oct	1998	23.1
Nov	1998	22.2
Dec	1998	18.0

Kodiak, Alaska, USA
Kodiak High School
Latitude: 58°N
Longitude: 152°W
Elevation : 35 m

Month	Year	Avg Temp
Jan	1999	-0.9
May	1998	6.4
Jun	1998	10.8
Jul	1998	12.8
Aug	1998	12.9
Sep	1998	9.9
Oct	1998	5.3
Nov	1998	2.7
Dec	1998	-1.5

5. Temperatures Around the World

Label each plot line:
a. latitude and
b. state/country



6. Days and Nights Around the World: Seasonal Changes in Number of Hours of Daylight

All dates are the 21th day of the month

Latitude: 70° North

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	NONE	NONE	0
Feb	8:14	4:34	8:20
Mar	6:04	6:32	12:28
Apr	3:35	8:46	17:11
May	NONE	NONE	24:00
Jun	NONE	NONE	24:00
Jul	NONE	NONE	24:00
Aug	3:36	8:46	17:10
Sep	5:46	6:17	12:31
Oct	7:49	3:58	8:09
Nov	NONE	NONE	0
Dec	NONE	NONE	0

Tromsö, NORWAY
Prudhoe Bay, ALASKA, USA
Clyde, Baffin Island, CANADA

Latitude: 57° North

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	8:28	4:15	7:47
Feb	7:23	5:25	10:02
Mar	6:09	6:26	12:17
Apr	4:50	7:25	14:35
May	3:41	8:24	16:43
Jun	3:15	9:08	17:53
Jul	3:48	8:43	16:55
Aug	4:49	7:35	14:46
Sep	5:53	6:12	12:19
Oct	6:56	4:52	9:56
Nov	8:04	3:47	7:43
Dec	8:47	3:29	6:42

Kodiak, ALASKA, USA
Glasgow, SCOTLAND
Copenhagen, DENMARK
Moscow, RUSSIA

Latitude: 38° North

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	7:22	5:21	9:59
Feb	6:52	5:55	11:03
Mar	6:12	6:23	12:11
Apr	5:26	6:51	13:25
May	4:55	7:18	14:23
Jun	4:47	7:36	14:49
Jul	5:04	7:28	14:24
Aug	5:30	6:55	13:25
Sep	5:57	6:08	12:11
Oct	6:24	5:24	11:00
Nov	6:57	4:54	9:57
Dec	7:22	4:54	9:32

USA: San Franci sco, CALIFORNIA
Charleston, W. VIRGINIA
Wichita, KANSAS
St. Louis, MISSOURI
Louisville, KENTUCKY
Pueblo, COLORADO
Richmond, VIRGINIA

Sendai, JAPAN
Tientsin, CHINA
Athens, GREECE
Cordoba, SPAIN
Seoul, S. KOREA
Izmir, TURKEY
Palermo, SICILY
Lisbon, PORTUGAL

Latitude: 26° North

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	6:58	5:44	10:46
Feb	6:41	6:06	11:25
Mar	6:12	6:22	12:10
Apr	5:41	6:36	12:55
May	5:21	6:52	13:31
Jun	5:19	7:05	13:46
Jul	5:30	7:02	13:32
Aug	5:45	6:40	12:55
Sep	5:58	6:07	12:09
Oct	6:12	5:37	11:25
Nov	6:32	5:19	10:47
Dec	6:53	5:23	10:30

Monterey, MEXICO
Kunming CHINA
Karachi, PAKISTAN
Luxor, EGYPT
Taipei, TAIWAN
Patna, INDIA
Riyadh, SAUDI ARABIA
Wau El Kebir, LIBYA

Latitude: 0°

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	6:18	6:25	12:07
Feb	6:20	6:27	12:07
Mar	6:14	6:20	12:06
Apr	6:05	6:12	12:07
May	6:03	6:10	12:07
Jun	6:08	6:15	12:07
Jul	6:13	6:20	12:07
Aug	6:09	6:16	12:07
Sep	6:00	6:06	12:06
Oct	5:51	5:58	12:07
Nov	5:52	5:59	12:07
Dec	6:04	6:12	12:08

Quito, ECUADOR; Nairobi, KENYA; Singapore, MALAYA

Latitude: 26° South

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	5:36	7:06	13:30
Feb	5:59	6:48	12:49
Mar	6:14	6:20	12:06
Apr	6:28	5:48	11:20
May	6:44	5:29	10:45
Jun	6:56	5:27	10:31
Jul	6:54	5:38	10:44
Aug	6:33	5:53	11:20
Sep	6:00	6:05	12:05
Oct	5:29	6:20	12:51
Nov	5:11	6:41	13:30
Dec	5:15	7:01	13:46

Pretoria, SOUTH AFRICA
Curitiba, BRAZIL
Brisbane, AUSTRALIA
Asuncion, PARAGUAY

Latitude: 38° South

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	5:11	7:31	14:20
Feb	5:46	7:00	13:14
Mar	6:14	6:20	12:06
Apr	6:42	5:34	10:52
May	7:09	5:04	9:55
Jun	7:26	4:47	9:21
Jul	7:19	5:13	9:54
Aug	6:47	5:39	10:52
Sep	6:01	6:05	12:04
Oct	5:16	6:33	13:17
Nov	4:45	7:07	14:22
Dec	4:44	7:32	14:48

Melbourne, AUSTRALIA
Auckland, NEW ZEALAND
Bahia Blanca, ARGENTINA
Curacautin, CHILE

Latitude: 70° South

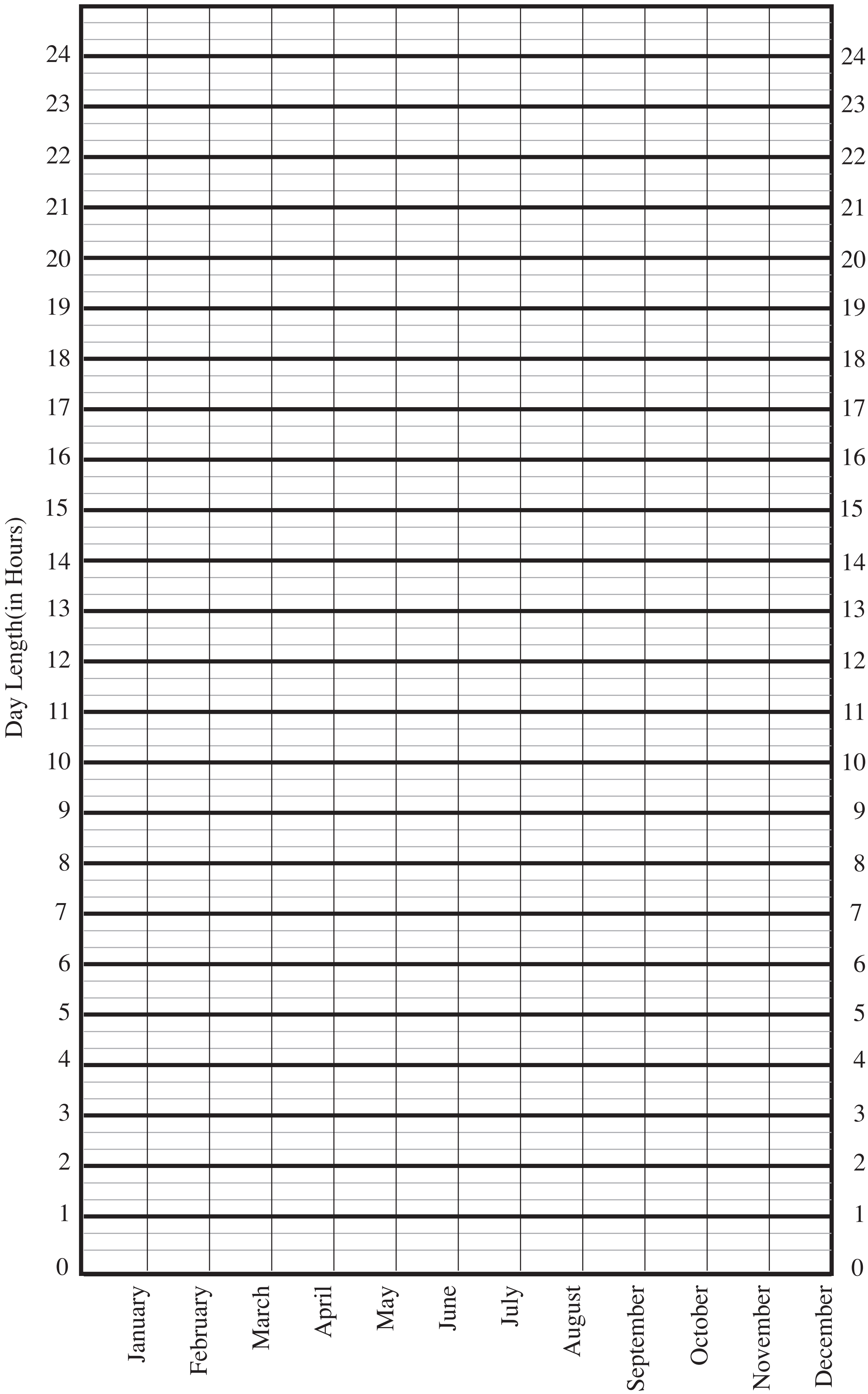
Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	NONE	NONE	24:00
Feb	4:09	8:35	16:26
Mar	6:10	6:21	12:11
Apr	8:19	3:57	7:38
May	NONE	NONE	0
Jun	NONE	NONE	0
Jul	NONE	NONE	0
Aug	8:24	4:03	7:39
Sep	6:00	6:07	12:07
Oct	3:37	8:15	16:38
Nov	NONE	NONE	24:00
Dec	NONE	NONE	24:00

ANTARCTICA

Data generated with Voyager by Carina software, Hayward, California

6. Days and Nights Around the World: Seasonal Changes in Number of Hours of Daylight

Label each plot line:
a. latitude and
b. state/country



NOTES:

Kinesthetic Astronomy

Grades:
5 - 8

Objectives:

- Students will be able to explain the spatial relationship between Earth and the Sun.
- Students will be able to model the movement of Earth around the Sun.
- Students will be able to define Solstice and Equinox.

Description:
Students act out the motions of Earth around the Sun over the course of one year, including the tilt, solstice and equinox.

Suggested Timing:
25 – 30 minutes.

National Standards
Content Standard D: As a result of their activities in grades 5 – 8, all students should develop an understanding of Earth in the solar system, 4: Seasons result from the variations in the amount of the Sun's energy hitting the surface, due to the tilt of Earth's rotation on it's axle and the length of day.

Vocabulary:

- Solstice
- Equinox
- Vernal
- Autumnal
- Rotation
- Revolution
- Orbit

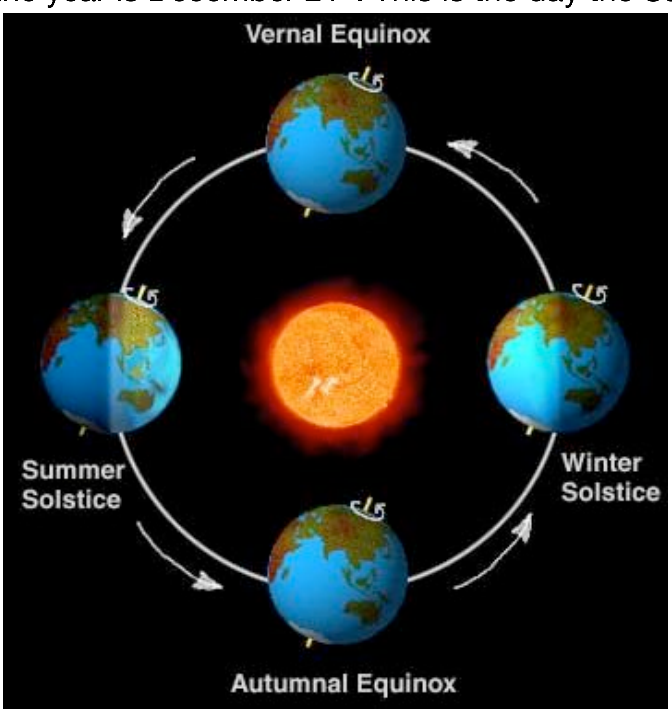
Materials: (One per group)

- Signs, one of each month.
- Object to represent the Sun
- Globe(s)
- Flashlight
- Object or sign to represent Polaris
- Optional: “East” and “West” popsicle sticks
- Optional: Zodiac constellation signs
- Optional: NASA Solar Pizza

Background Information:

Earth revolves around the Sun once per year. The seasons on Earth are caused by the tilt of Earth on its rotation axis, which is approximately 23.5 degrees with respect to it’s plane of orbit. As Earth revolves around the Sun its axis is continually tilted in the same direction. If you extended the line of the axis into space it would touch Polaris, or the North Star. As Earth rotates around its axis Polaris appears to remain in the same place while all the stars rotate around it.

Once a year Earth’s northern hemisphere is tipped toward the Sun. Once a year it is tipped away from the Sun. These days are called Solstices – the longest and shortest day of the year. In the northern hemisphere the longest day of the year falls on June 21st. This is the day when the Sun illuminates the largest area of the northern hemisphere, resulting in more hours of daylight as Earth rotates. The shortest day of the year is December 21st. This is the day the Sun illuminates the least surface area and the northern hemisphere receives the fewest hours of daylight.



Source: http://science.nasa.gov/headlines/y2002/21jun_shadows.htm

Twice a year Earth’s orientation in relation to the Sun is perpendicular. These days are called Equinoxes – meaning equal day and equal night. All areas of the northern and southern hemisphere are equally illuminated because of this perpendicular orientation. On these two days of the year there are 12 hours of light and 12 hours of darkness everywhere on earth. The autumnal, or fall, equinox occurs on September 22nd, and the vernal, or spring, equinox occurs on March 20th.

Content:

Predict: (Engagement and assessing prior knowledge)

- What is a year?
- Draw how Earth moves around the Sun.
- What is a day?
- What does Earth's orbit look like?

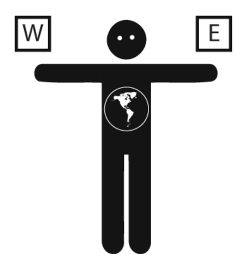
Method: (Body of the lesson)

Have students stand in a circle with an object or light bulb in the center of the room to represent the Sun. Give each student two popsicle sticks, one with an E and the other with a W. (Students can also make an "E" and "W" with their fingers.) Hold a globe in front of you (a t-shirt with a map on it works well too.)

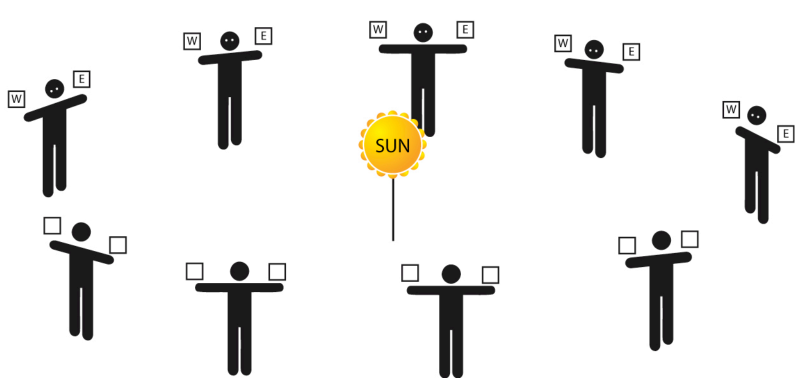
Explain to students that they are going to pretend that they are Earth.

Ask: If you are Earth, where is your north pole? (On top of your head)

Ask: Using the globe as a reference, which hand should hold the East stick and which hand should hold the West stick? Remember that North is up and South is down. (Left = East, Right = West)



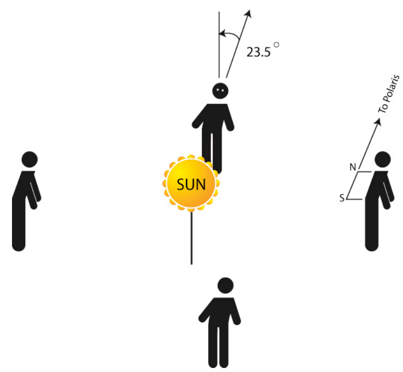
Ask: Based on our observations, we know that the Sun rises in the east and sets in the west. Imagine there is a man standing on Mt. Nose (your nose). Which way should you rotate so that the Sun rises to the east of Mt. Nose and sets to the west? (Counterclockwise)



Instruct students to stand so that its Sunrise, noon, Sunset, then midnight on Mt. Nose. Have them do this several times.

Explain that earth revolves around the Sun in the same direction as it rotates on its axis: Counterclockwise, as seen from above the north pole.
Instruct students to walk in a circle counterclockwise, making one trip around the Sun and ending back where they started.

Explain that earth is tilted on its axis towards Polaris, or the North Star. Have students tilt themselves so their heads are lined up with a spot/poster/sign on the wall representing Polaris.



Instruct students to repeat a day's rotation, maintaining their tilt. (Make sure their heads are always pointed towards Polaris, this can be tricky for some students.)

Instruct students to repeat the year's revolution, adding in tilt, and then add in the day's rotation. (Note: Some kids might get dizzy and fall down, be prepared.) At this point have students stop and pass the globe around the circle, being careful to maintain its tilt.

Ask: What do you notice about Earth as it revolves around the Sun? Take several observations, and guide students to the realization that at one time it is pointing towards the Sun, and at another time it is pointing away from it.

Instruct students to observe the tilt of Earth on opposite sides of the Sun.

Ask: Where are two places where Earth's tilt compared to the Sun is the same? Where are two places where its tilt compared to the Sun is opposite?

Explain that these places are called the Solstice and Equinox. Introduce the terms Vernal and Autumnal. Pass the globe around again.

Optional: Put up signs labeling the locations of the Solstices and Equinoxes.

Instruct students to make one revolution around the Sun and each time they pass a solstice to raise their hand. Do the same with equinox.

Ask: We have a summer solstice, where the northern hemisphere gets the most hours of daylight, and when summer officially starts. Use the flashlight at this point to illustrate which hemisphere is getting the most direct Sunlight.
Which solstice is the summer solstice? Which month do you think this occurs in? Where is the winter solstice?
You may want to take this opportunity to talk about what causes seasons.

Ask: Where in earth's orbit is June? Where is December? Label these points on the wall.

Instruct students to find the spot around earth's orbit where their birthday would be located. Remind them that Earth rotates counterclockwise and where they decided that the summer and winter solstices are located.

Optional: Place signs for the months around the room in the correct spot. Add zodiac constellation signs as well.

To conclude have students repeat the motions of a year once more.

Optional: Solar Pizza Activity
Stand at one end of a hallway and have students guess where Earth would be if the Sun were the size of the solar pizza. Give students time to space themselves out, and then pace off the correct distance.

Have students draw a diagram of Earth's orbit around the Sun then correctly label the axis, solstices and equinoxes.

Live-It: (Assessment questions)

- (Knowledge) What is a year?
- (Comprehension) Describe how Earth orbits around the Sun.
- (Application) Use classroom materials to construct a 3D image showing a Solstice or Equinox.
- (Analysis) Compare and contrast Solstice and Equinox.
- (Synthesis) Use what you have learned to make a poster to teach someone about Solstice or Equinox.
- (Evaluation) Pluto's axis is tilted at an angle of 97 degrees. Describe what seasons would be like on Pluto **and** compare them to seasons on earth.

Extension:

Have students create a four-page booklet, one page per season, showing the orientation of Earth, a seasonal landscape (Sunshine and trees in full foliage for summer), and a short poem about the activities that occur in that season.

Resources:

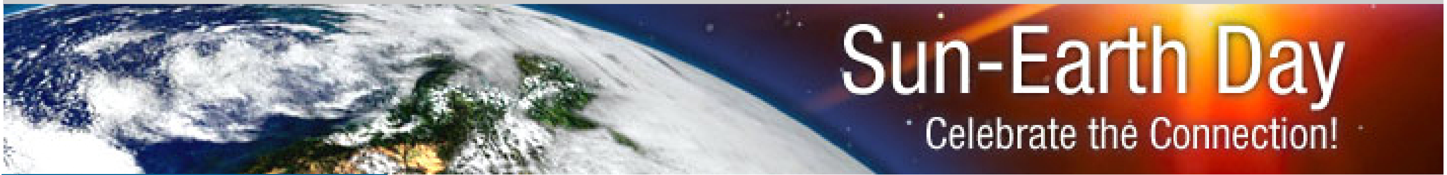
Extensive worksheets created by SDSC
http://education.sdsc.edu/teachertech/downloads/k_astronomy.pdf

Carl Sagan's video called "The Pale Blue Dot." Find it at
www.youtube.com

Seasons Animation:
http://highered.mcgraw-hill.com/sites/007299181x/student_view0/chapter2/seasons_interactive.html

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

http://sunearthday.nasa.gov



Public Outreach
- Make and Take Activities

Scale Model of Sun and Earth

About this Activity

This activity explores the relative size of Sun and Earth as well as the distance between them.

Below right: Looking toward the model Sun from the model Earth. A pre-measured piece of string was used to mark the appropriate distance for the scale model.

What You'll Need

- copies of the Sun and Earth handout sheet (see next page)
- measuring tape
- a large room or a long hallway where you will be able to walk 65 feet in a straight line without many obstacles
- (optional) scissors
- (optional) 65 feet length of string

Note: Copies of our readymade cardstock version of this Sun-Earth scale model are available for free by request. If you need copies for a specific event or education program, email us at outreach@cse.ssl.berkeley.edu

Both English and Spanish versions available.

Preparation

Measure 65 feet (the distance between Sun and Earth in the scale of our model) from where you will be doing this activity and mark the distance for later reference. If you do not have a fixed location, we find it helpful to have a piece of string cut to exactly 65 feet in length for you to use as a reference during the activity.

If you want your participants to guess the size of the Earth, you might want to keep the image of Earth out of sight by cutting off the top of the hand-out page along the dash line.

To Do and Notice

1) Show participants the image of the Sun. (This is a good opportunity to notice what the Sun's surface look like and to point out that the Sun is not as featureless and uniformly bright as it might look to our eyes.) Ask participants to guess how big the Earth would be if the Sun is the size of this image.

2) Reveal the answer by showing the image of Earth. (Optional: you might want to let the participants cut out the Earth and the disc of the Sun instead of using the 2 sections of the handout sheet.) Ask participants to guess how far the model Earth should be from the model Sun. We suggest allowing participants to walk to where they think the distance should be. We find it helpful to tape the model Sun to a spot around eye-level at the starting point and have the facilitator walk with the participants. The model Earth should be 65 feet away from the model Sun. Use the marker you placed earlier (or the cut piece of string) to guide you.

3) (Optional) At 65 feet away, look back towards the model Sun. Notice how big it looks to you at this distance. At this scale, the model Sun should be about the same size as the actual Sun would appear to us here on Earth. (It is always a good idea to remind participants not to look directly at the Sun.) Since this part requires a basic understanding of ratio and scale model, it might not be appropriate for all participants.

Activity Notes

"Why does the Sun I see in the sky look different from this picture?" is a common question. The Sun image here was taken by a telescope that is mounted on a satellite in space (the TRACE mission to be exact). Besides being able to see farther than we can and without the clouds and Earth's atmosphere in the way, this telescope also looks at a different kind of light. The Sun gives off different kinds of energy, only part of that is in the form of visible light which we can see. The telescope that took this picture looks at the extreme ultraviolet (EUV) light coming from the Sun.

Related Websites

TRACE Education Resources: the Sun, its structure, and the satellite mission.
http://trace.lmsal.com/Public/eduprodu.htm

Stanford Solar Center: About the Sun
http://solar-center.stanford.edu/about/

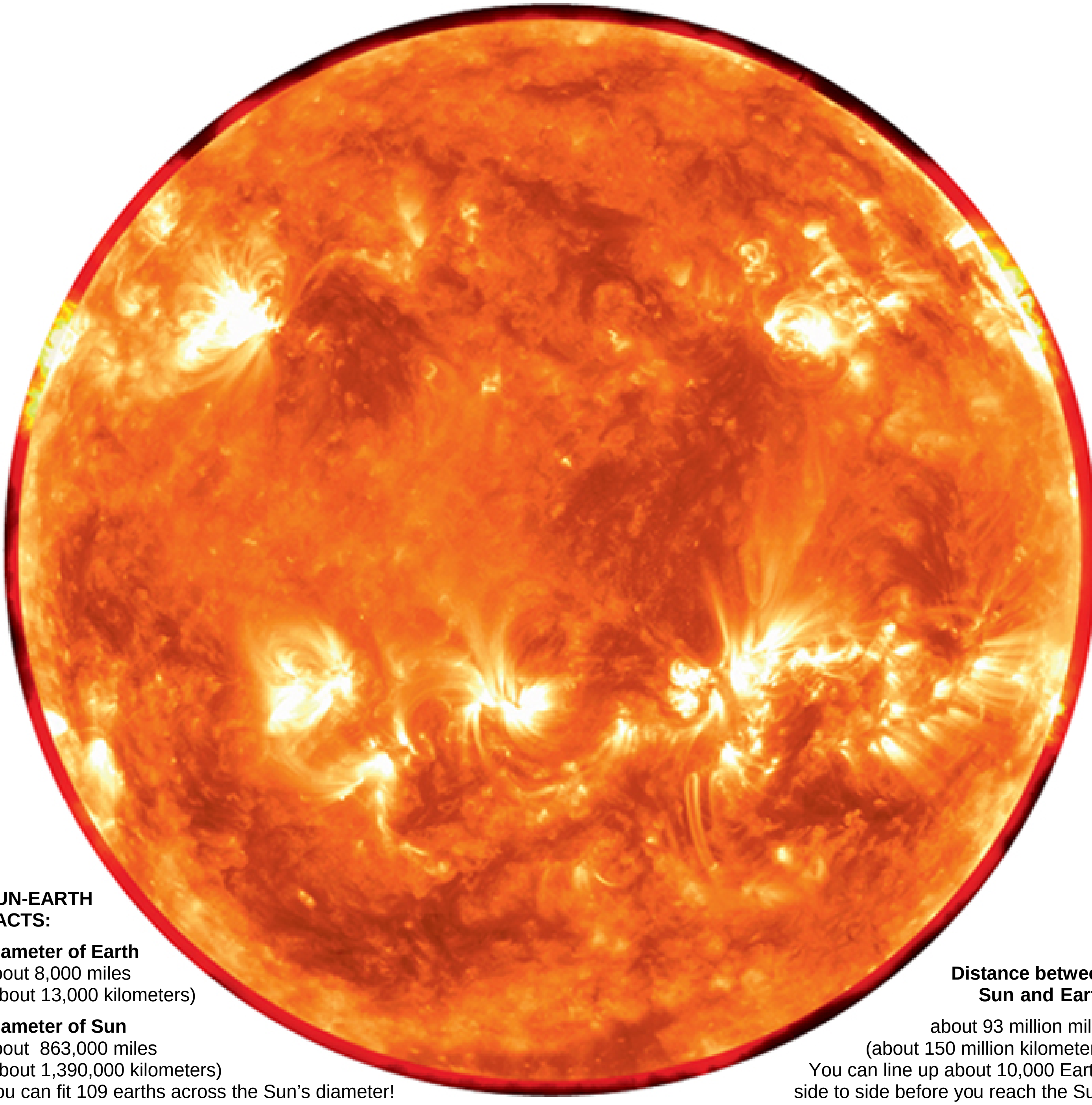
NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

http://sunearthday.nasa.gov

1. Cut out the images of the Sun and the Earth.
2. To demonstrate the distance between Sun and Earth at this scale, separate the images 65 feet (about 20 meters) apart. This distance represents approximately 93 million miles (150 million kilometers).

This image of Earth is scaled to the proper size in relation to the image of the Sun below.

Earth 



SUN-EARTH FACTS:

Diameter of Earth
about 8,000 miles
(about 13,000 kilometers)

Diameter of Sun
about 863,000 miles
(about 1,390,000 kilometers)
You can fit 109 earths across the Sun's diameter!

Distance between Sun and Earth:
about 93 million miles
(about 150 million kilometers)
You can line up about 10,000 Earths side to side before you reach the Sun.

Measuring Time

Grades:
5 - 8

Objectives:

- Students will be able to define a day as one rotation of Earth.
- Students will be able to explain that time can be measured by the position of the Sun in the sky as Earth rotates.
- Students will be able to explain that shadows are indicators of Earth's rotation and can be used to measure time

Description:
Students model the rotation of Earth over one day, holding a flashlight for the Sun and a blow up globe with objects attached to make it 3D, and record their observations. They then take those observations and create a "device" that will let them track time. Students conclude by taking them outside to test their effectiveness.

Suggested Timing:
25 – 30 minutes.

National Standards
Content Standard D: As a result of their activities in grades 5 – 8, all students should develop an understanding of Earth in the solar system, 1: The Sun, an average star, is the central and largest body in the solar system. 4: Seasons result from the … rotation on it's axle and the length of day.

Vocabulary:

- Gnomon
- Clockwise
- Counter clockwise
- Rotate
- Revolve

Materials: (One per group)

- Blow up globe
- 6 Tiny plastic people/trees
- East and West Popsicle sticks
- Tape
- Flashlight
- Scissors
- Card stock, several sheets
- Sundial pattern

Background Information:

The Solar Dynamics Observatory's mission is to study the changing Sun. Earth's changing position in relation to the Sun and how humans have used that relationship is a fundamental concept.

Sundials: The original timepiece. Today we have examples of Sundials used in Egypt about 1500 B.C., which were discovered by archeologists. Egyptians began using a T-shaped "time stick" made with one vertical pole and one crossbar. The names of five hours were written on the pole. In the morning the pole was placed so that it faced east. The shadow of the crossbar would then fall across the pole and move toward the crossbar until noon. In the afternoon the stick was turned to face west.

Sundials evolved through the middle ages and renaissance to include more detail and a more accurate shape. Sundials were once used to correct mechanical clocks, and people would set their pocket watches by the Sundial in the center of town. With the growing popularity of traveling quickly over large distances by train, the need for time zones became apparent. Because of the curve of Earth, each town along the track would have a slightly different time. The need to have a standard time to keep the trains on schedule was needed and so the US was divided up into time zones.

Sundials are not extremely accurate timekeepers for several reasons. We live in a world divided into time zones one hour wide. For Sundials to be accurate you would have to be located in the center of the time zone, however people live all over time zones, not just the center. Also, the length of the day changes as Earth moves closer to and farther from the Sun during the year. A day is shorter in January than in June. This can cause differences between our "Standard Time" and "Solar Time" greater than +/- 10 minutes which shifts over the course of the year.

In this lesson students will understand that Sundials work by casting a shadow on the ground that moves as Earth rotates on its axis. The Sun appears to move across the sky from east to west, so the shadow will move across the dial from west to east, left to right if aligned north, or in other words, "clockwise." When the Sun is at it's *zenith*, or highest point at midday, the shadow cast by the *gnomon*, or pointer, will be shortest. As the Sun rises the shadow gets shorter, and as it sets the shadow will get longer and longer.

Students will be able to model the motion of shadows on the ground by simulating Earth over the course of one day. Earth rotates on its axis counterclockwise, which can be deduced from knowing that the Sun rises in the east and sets in the west.

<u>Content:</u>

Predict: (Engagement and assessing prior knowledge)

Ask: How do we measure time?
- Have students brainstorm ways to measure time and list them in their notebooks or on the whiteboard.

Ask: Have there always been watches and clocks? How can we measure time without a watch or clock?
- Brainstorm ideas with students and write on whiteboard

Method: (Body of the lesson)

How can we measure time without a watch or clock?

Tell students that they are going to construct a device to track time, but first we need to understand some things about Earth and the way it works. Then they will build a model and make observations to find the answer to their driving question: How can we measure time without a watch or clock?

<u>Ask</u>: What is a day?
- Take several student ideas

Have students stand in a circle with an object or light bulb in the center of the room to represent the Sun. Give each student two popsicle sticks, one with an E written on it and the other with a W. Having students make an "E" shape and a "W" shape with their fingers works just as well. Hold a globe in front of you (a t-shirt with a map on it works well too.)

Explain: Each student in the circle represents Earth.

Ask: Using the globe as a reference, which hand should hold the East stick and which hand should hold the West stick? (Left = East, Right = West) Clarify that when you are looking at Earth east would be to the right and west to the left, but for this activity students are acting as Earth, so left would be east and right would be west. Use probing questions like “Where do we live now?” and “Where is the west/east coast?” and have them point to it on your globe.

Ask: Based on our observations, we know that the Sun rises in the east and sets in the west. Imagine there is a man standing on Mt. Nose (your nose). Which way should you rotate so that the Sun rises to the east of Mt. Nose and sets to the west? (Counterclockwise, or, to the left)

Instruct students to stand so that its Sunrise (Sun to the east), noon (Sun overhead), Sunset (Sun to the west), and midnight (facing away from the Sun) on Mt. Nose. Have them do this several times.

> * **Note**: If the class has completed the Kenestetic Astronomy activity already, the above portion of the lesson may be skipped. Instead refresh their memories or have a volunteer come and act it out for the whole class to see.

Now that students understand what a day is, hand out globes, plastic figures, and flashlights to each group. Tell them to tape 5 figures to the surface of their globe, evenly spread around, so that they look like they are “standing” on Earth.

Have students shine the flashlight on the globe, simulating the Sun, and rotate it in the correct direction (counterclockwise when viewed from the north pole).

Have students take turns holding the flashlight, rotating the globe, and writing down their observations.

Ask: What did you observe?
- Take student responses.
- Guide discussion to the shadows cast by the figures and the fact that they moved as Earth rotated.

Live-It: (Assessment/application assignment)

Instruct: Your task now is to build something that will let you keep track of time using shadows.
- Hand out card stock, tape, and any other materials you’d like them to experiment with.
- When students think they are done have them show you with the flashlight how the shadow moves clockwise as the “Sun” rises and sets.

- Discuss marking the device at Noon, Sunset, and Sunrise
- In a short paragraph, have students explain how their device works.

Extension:

Students can create a garden Sundial on the playground, using their body as the gnomon and chalk and a compass for markings.

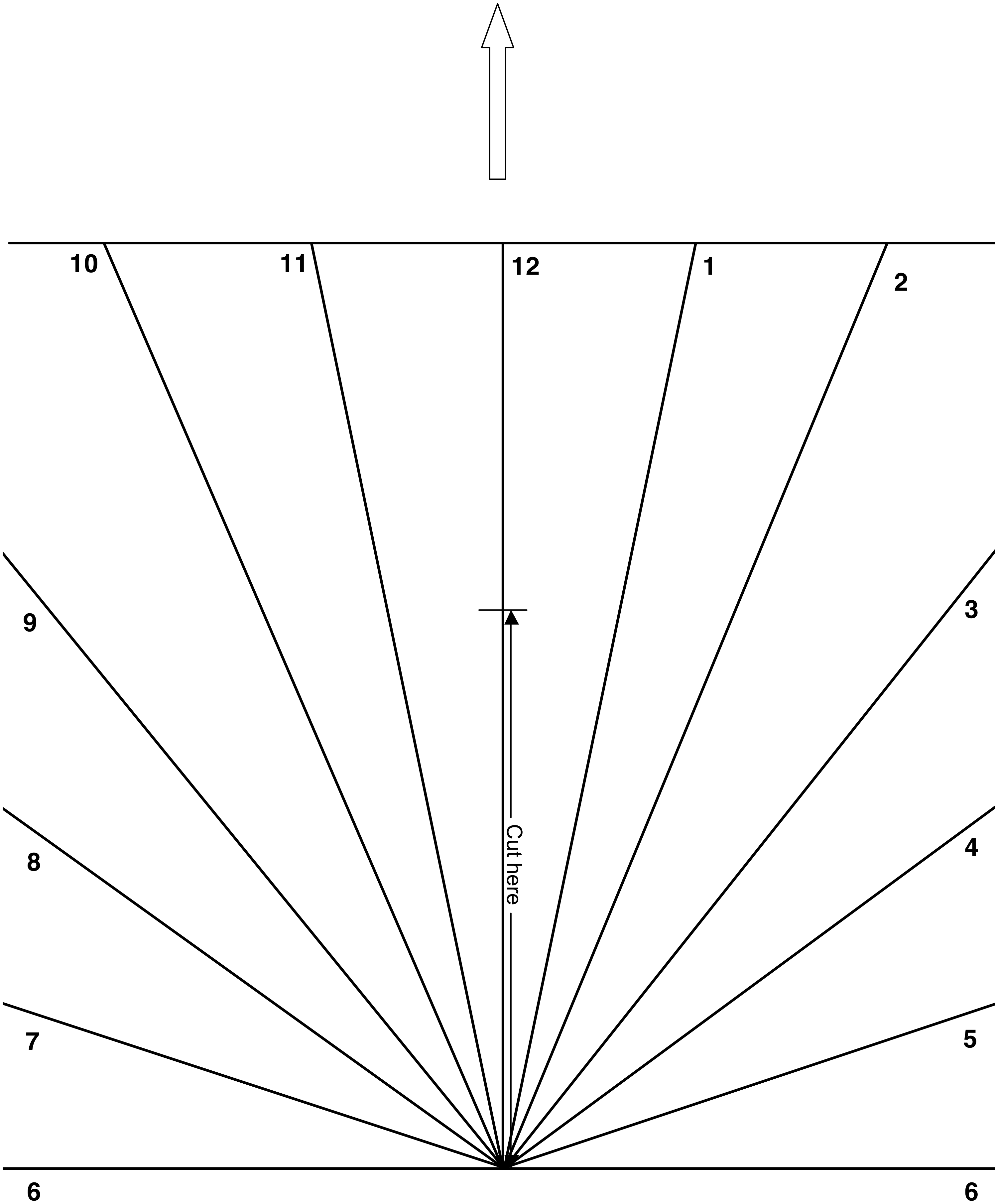
Resources:

A guide to Sundials. Includes local noon calculator.
http://www.Sundials.co.uk/

Sundial interactive activities.
http://www.fi.edu/time/Journey/Sundials/interactsd.htm

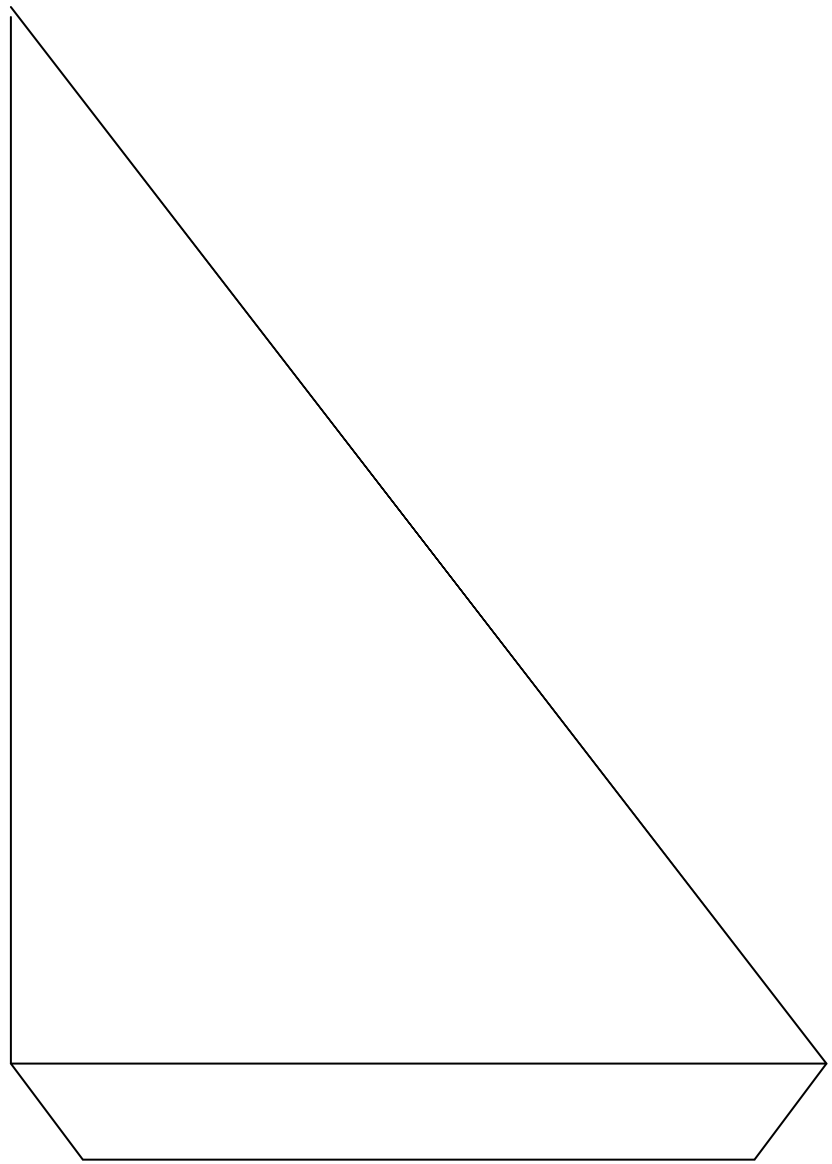
Detailed information and activity ideas
http://hea-www.harvard.edu/ECT/Daymarks/

Point this North



Sundial Base

The Gnomon



NOTES:

Solar Observations

Grades:
5 - 8

Objectives:
- Students will be able to identify Sunspots and prominences on the Sun.
- Students will be able to explain that the Sun moves across the sky in a predictable motion.

Description:
Students spend the class period outdoors using pinhole cameras, solar telescopes, and solar viewing glasses to make solar observations and look for Sunspots.

Suggested Timing:
25 – 30 minutes.

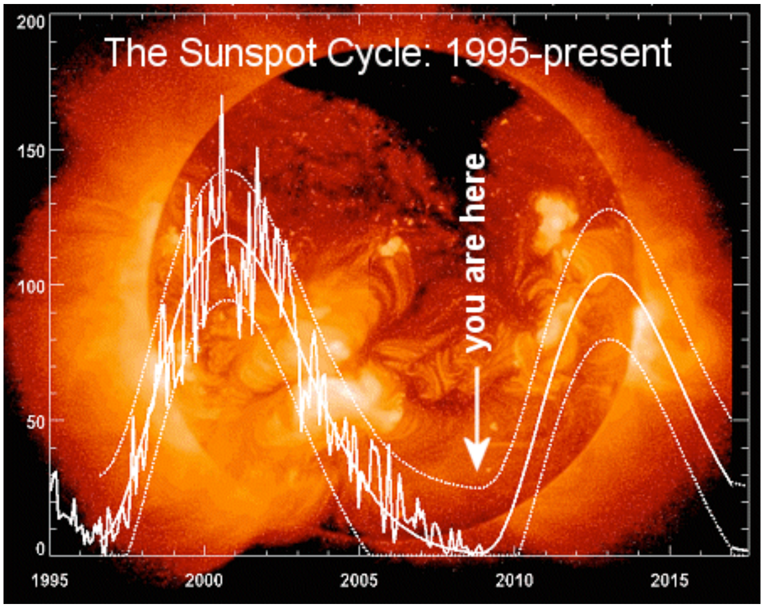
National Standards
Content Standard D: As a result of their activities in grades 5 – 8, all students should develop an understanding of Earth in the solar system, 1: The Sun, an average star, is the central and largest body in the solar system.

Vocabulary:
- Sunspot
- Prominence
- Disc

Materials: (One per group)
- Pinhole cameras – meter stick and two index cards (Solar viewing tool constructed from cardboard and meter sticks. See Lesson 1: The Size of the Sun)
- Solar telescope (Or filter)
- Eclipse Glasses
- Solar feature worksheets

Background Information:

The first telescopic observations of Sunspots occurred in 1610 by several astronomers throughout Europe. Early recordings of Sunspots show that the Sun goes through an 11 year of activity and inactivity. Sunspots increase in number, then gradually decrease, then increase again, creating the Sunspot cycle. Scientists believe the Sunspot cycle is linked to the Sun's complex magnetic field, which becomes tangled as the Sun rotates.



Credit: David Hathaway, NASA/MSFC

Our Sun is a dynamic ball of plasma, fusing hydrogen and helium gasses and releasing the energy through radiation. It has distinct features caused by electromagnetic forces, which include Sunspots and prominences. These two features are easily observable to amateur astronomers.

Prominences are clouds of material suspended above the surface of the Sun by loops of magnetic field. Prominences and filaments are actually the same thing, except that prominences are seen projecting out above the limb, or edge, of the Sun. Both filaments and prominences can remain in a quiet or quiescent state for days or weeks. However, as the magnetic loops that support them slowly change, filaments and prominences can erupt and rise off of the Sun over the course of a few minutes or hours. They are often visible during a total solar eclipse.

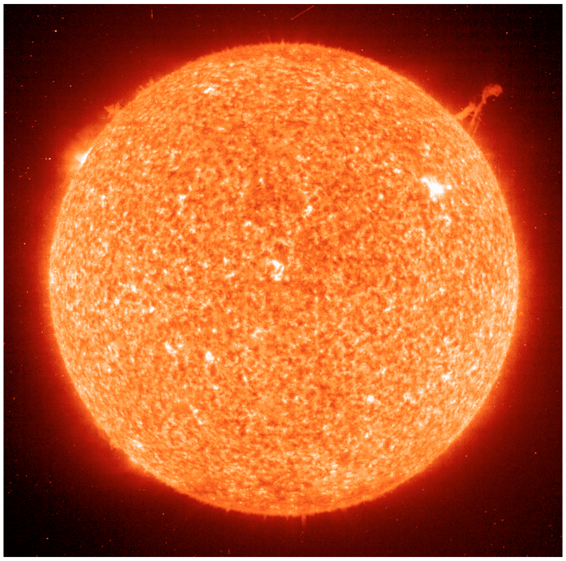


Image From: umbra.nascom.nasa.gov

Sunspots appear as dark spots on the visible surface of the Sun. Temperatures in the dark centers of Sunspots drop to about 3700 K (compared to 5700 K for the surrounding photosphere). They typically last for several days, although very large ones may live for several weeks. Sunspots are magnetic regions on the Sun with magnetic field strengths thousands of times stronger than Earth's magnetic field. Sunspots usually come in groups with two sets of spots. One set will have positive or north magnetic field while the other set will have negative or south magnetic field. The field is strongest in the darker parts of the Sunspots - the umbra. The field is weaker and more horizontal in the lighter part - the penumbra. The largest Sunspot ever recorded was visible in March and April 1947 and covered an area of over 7,000 million square miles; about a hundred Earths could be fitted into this area!

Image From: http://science.nasa.gov/

Content:

Predict: (Engagement and assessing prior knowledge)

Have students take a moment and draw what they think the Sun looks like. Student drawings may range from cartoon images to simple yellow circles.

Ask: What do you think we would find if we were able to observe the Sun like we can observe the moon or other celestial bodies?

Take some student answers, then explain that they will be using a pinhole viewer, eclipse glasses, and solar telescope to make solar observations. Explain that they are looking for Sunspots and, if you have a solar telescope, prominences, and that both are caused by the magnetic field of the Sun. Sunspots are cooler regions where the magnetic field exits then enters the surface of the Sun, and prominences are lines of plasma that follow the magnetic field lines.

If a solar telescope is not available, filters for a regular telescope can be purchased online (see resources). This activity can also be completed without the use of a telescope.

Method: (Body of the lesson)

Hand out student worksheets. Take students outside and give them time to make observations of the solar *disc*- the visible image of the Sun - using a pinhole viewer and other available technology.

Caution: DO NOT look directly at the Sun.

Some students may have trouble distinguishing what they are looking at. Ask questions like, "What do you see?" and "How would you draw what you see?"

Have students record their observations on their worksheets.

Note: Check online to see the current state of the Sun and the weather before doing this activity. Going outside on a calm solar day, even if it is Sunny out, can be defrauding for students. Choosing a day when there will be observable Sunspots will be more enjoyable for everyone. Use: http://sohowww.nascom.nasa.gov/data/realtime-images.html

Live-It: (Assessment/application assignment)

Have students go online (or project the website for the class) and compare their drawings to the SOHO images of the Sun:
http://sohowww.nascom.nasa.gov/data/realtime-images.html

Have them answer the following questions:

- Compare and contrast the image you drew and the images SOHO took.
- How are they different? How are they the same?
- Why are some images different colors? (Discuss the electromagnetic spectrum and how those images were taken in different wavelengths. This is also a good opportunity to discuss false color and how it helps scientists analyze images taken in wavelengths invisible to the human eye.)
- What are Sunspots?

<u>Extension:</u>

The Space Weather Action center allows classrooms to monitor solar activity with real-time data from multiple solar missions. The website provides easy to use tutorials, interviews with scientists, videos and more. Students can choose a single Sunspot, and record it's location on a solar "disc" (circle on a sheet of paper) over the course of a week, or pose their own research question and use the data from the Space Weather Action Center Website to answer it.

Space Weather Action Center: http://Sunearthday.nasa.gov/swac/

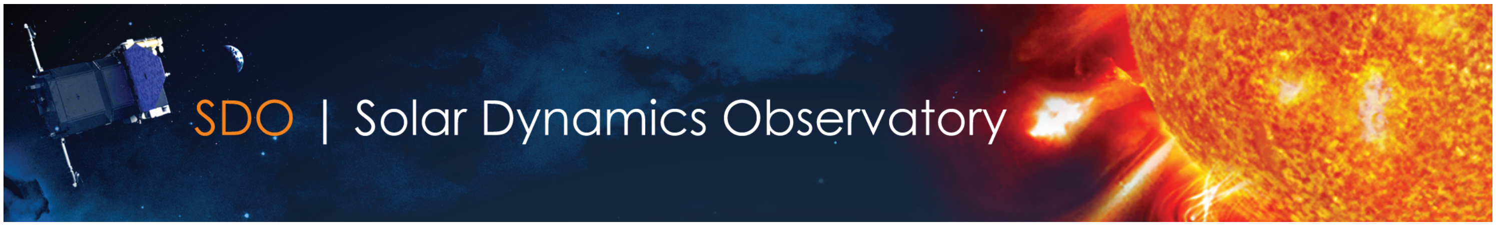
Resources:

The Solar Dynamics Observatory:
http://www.youtube.com/watch?v=PZEKINoI9aU

Simple Pinhole viewer instructions:
http://solar-center.stanford.edu/observe/

Current SOHO Images of the Sun:
http://sohowww.nascom.nasa.gov/data/realtime-images.html

Sources for Solar Filters:
http://www.skyandtelescope.com/equipment/vendors/3304076.html



Solar Observations

Name: ________________

Date: ________________

Time: ________________

Conditions Outside: (Circle all that apply)

Clear

Haze: Heavy Medium Light

Clouds: Heavy Medium Light Drifting Intermediate

Wind: Yes/No

Instruments used in observations:

____

____

Solar Disk

The Sun and Magnetic Fields

Lesson and text adapted from "Live from the Aurora, Educator's Guide"
http://stargazers.gsfc.nasa.gov/pdf/products/educator_guides/aurora_educators_guide.pdf.

Grades:
5 - 9

Objectives:
- Students will be able to map a magnetic field.
- Students will be able to explain that invisible fields surround magnets.
- Students will be able to explain that magnetic fields on the Sun are visible in Sunspots.

Description:
Students will simulate Sunspots by using iron filings to map magnetic fields around a bar magnet. Students map the magnetic field surrounding two dipole magnets, both parallel and anti-parallel alignment. Students apply vector measurements to their field maps. Then students examine the field arrangement around complex arrangements of the dipole magnets.

Suggested Timing:
45 – 60 minutes.

National Standards
Content Standard E: As a result of their activities in grades 9 – 12, all students should develop an understanding of understanding science and technology, 5: Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

Content Standard D: As a result of their activities in grades 9 – 12, all students should develop an understanding of forces, 1: Objects change their motion only when a net force is applied. 3: The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them.

Vocabulary:

- Magnetic Force
- Orientation
- Field
- Dipole

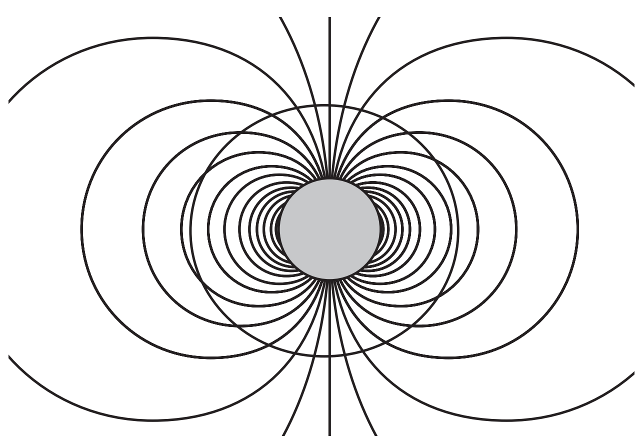
Materials: (One per group)

- Large sheets of paper
- Two cow magnets (strong bar magnets)
- Iron Filings (http://www.teachersource.com/)
- Worksheet

Background Information:

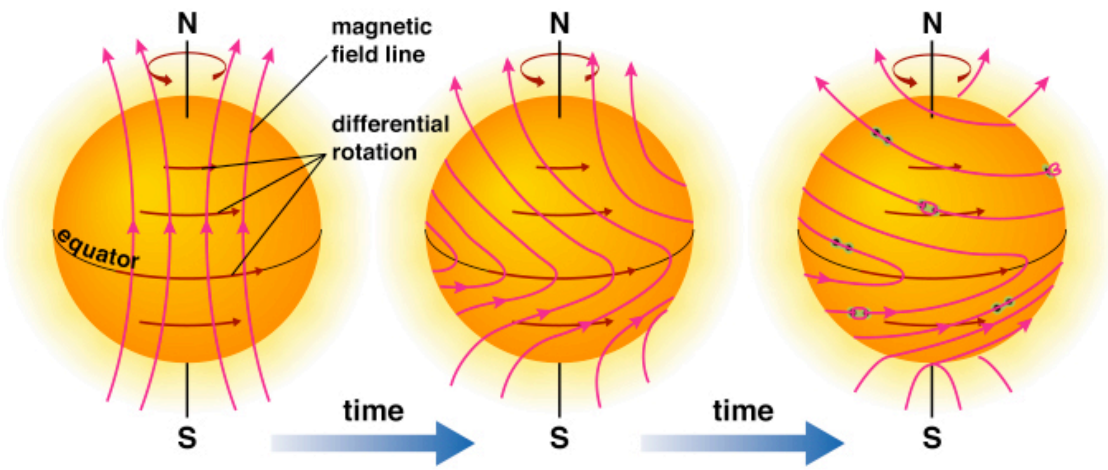
Humans have been aware of and made use of the magnetic field of Earth for the past 2 millennia. Mariners, following the example of the Chinese, used the magnetic properties of magnetite and magnetized metals to find their way relative to the fixed orientation of the compass needle in Earth's magnetic field. Today, we use magnets in a variety of ways, from floating fast spinning CDs in our computers, stereos and TVs, to magnetic resonance imaging, to sticking paper to our refrigerators. Magnetism is a noncontact force, meaning the magnet can affect materials across an intervening space. We do not have to be at the location of the source object to detect it. We say that a magnet creates a magnetic field or a region of influence in the space around the magnet.

The bar magnet is the prime example of a dipole magnet. A spherical magnet in an otherwise empty region of space would have a magnetic field approximately modeled in the figure below.



While Earth's magnetic field looks similar to the one in the image above, the Sun's field is significantly more complex because the Sun is not a solid.

Material at the equator rotates faster than material at the poles, causing the magnetic field to stretch and twist. Over the course of the eleven-year Sunspot cycle the field becomes so twisted that parts of the field break through the Sun's atmosphere, carrying material with them.



From The Essential Cosmic Perspective, by Bennett et al.

The material above the Sun's surface appears as prominences. Sunspots, or the points where the magnetic field exits and enters the surface of the Sun have "north" and "south" poles. This is why they always appear in pairs.

Image From: http://science.nasa.gov/

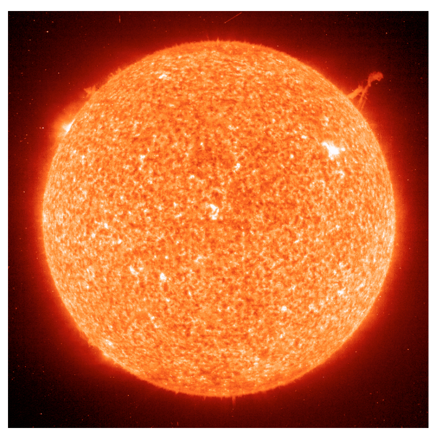


Image From: umbra.nascom.nasa.gov

Content:

Predict: (Engagement and assessing prior knowledge)

Ask: How do you know a magnet is a magnet? Where does magnetic force begin and end around a magnet?

Try to elicit these responses from students' previous experience with magnets.
- Magnets affect other magnets and metals.
- Magnetic influence or strength is not related to size of magnet.
- Magnetic influences extend through space, but get weaker with distance.
- Magnets have well differentiated ends or poles.
- There are two poles.
- Like poles repel; unlike poles attract.

Method: (Body of the lesson)

Hand out materials. Instruct students to position the magnets as show in each image, lay a sheet of paper over the top, and sprinkle iron filings on the sheet of paper.

Show students how to pour the iron filings back into their container without spilling them. Tell them to use caution because they are very hard to clean up and will also stick to the magnets.

Instruct them to draw the pattern of filings that they see, then carefully pour them back into their container before rearranging the magnets into the next configuration.

Give students 20-30 minutes to complete a activity. Circulate, answering questions.

Questions can be asked motivating students to think critically about the data and the data collection procedure. Some suggestions follow.
- What happens when the two magnets are aligned, positive to positive? Negative to negative?
- Can you tell which field line is from which magnet?

Show students the image attached to this lesson. Explain that these are Sunspots. In the first image students see a visible light image Sunspots.

Ask: Why do you think the Sunspot is darker than the surrounding area?
Take a few answers then explain that the dark area is cooler than the surrounding bright areas.

Explain that second image is a MDI Magnetogram, an image of magnetic field polarity. The black spots are negative polarity while the white spots are positive polarity.

Live-It: (Assessment/application assignment)

Have students answer the following questions:
- What is the map representing?
- What is happening between the magnets?
- Suppose you were able to map the field in a plane 30 cm above the plane of the source. What sort of a map would you predict seeing? Can you use the map you have made to demonstrate your prediction is reasonable?
- How are the iron filings like Sunspots?

<u>Extension:</u>

Students can research the Maunder Minimum, an unusually low time in the Sunspot cycle, and compare it to the current Sunspot cycle.

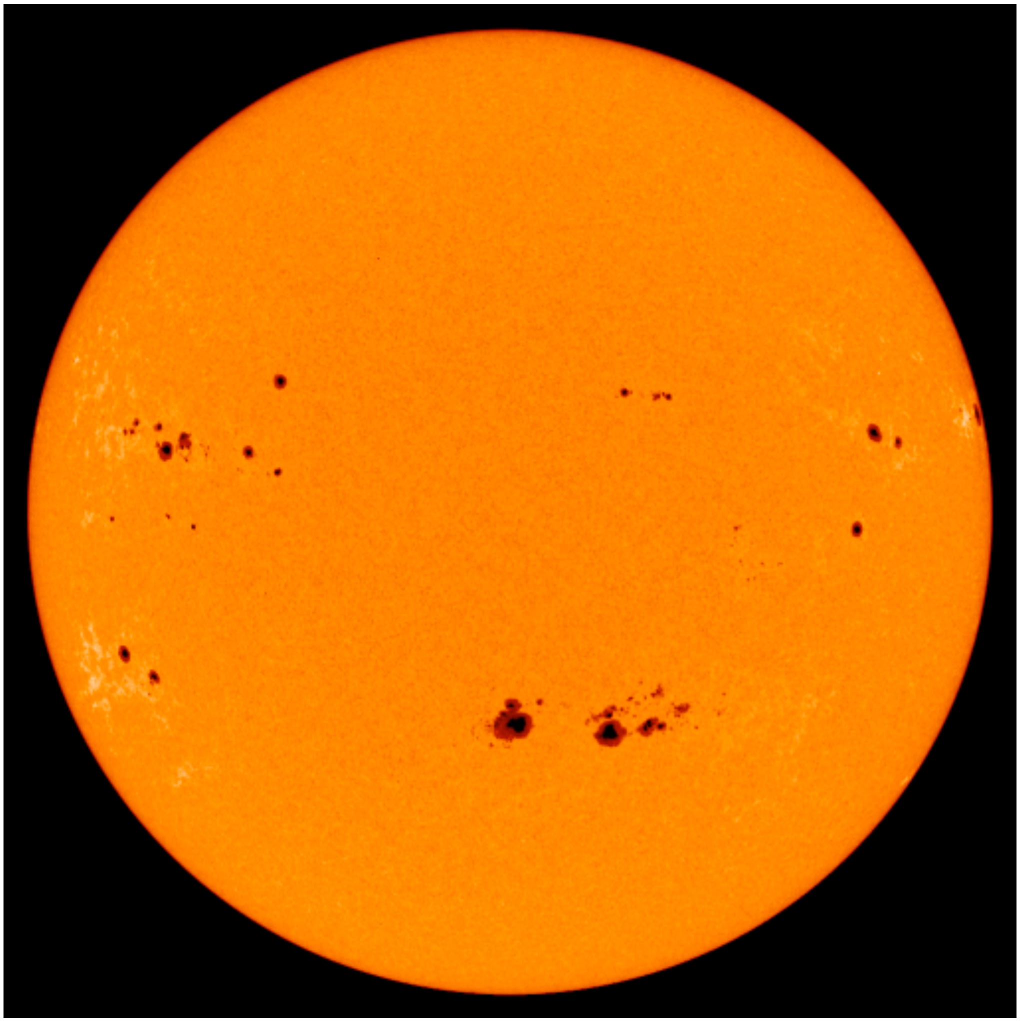
<u>Resources:</u>

The Solar Dynamics Observatory:
http://www.youtube.com/watch?v=PZEKINoI9aU

Little SDO Looks Inside the Sun's magnetic field:
http://www.youtube.com/watch?v=mvtbPJM5o94

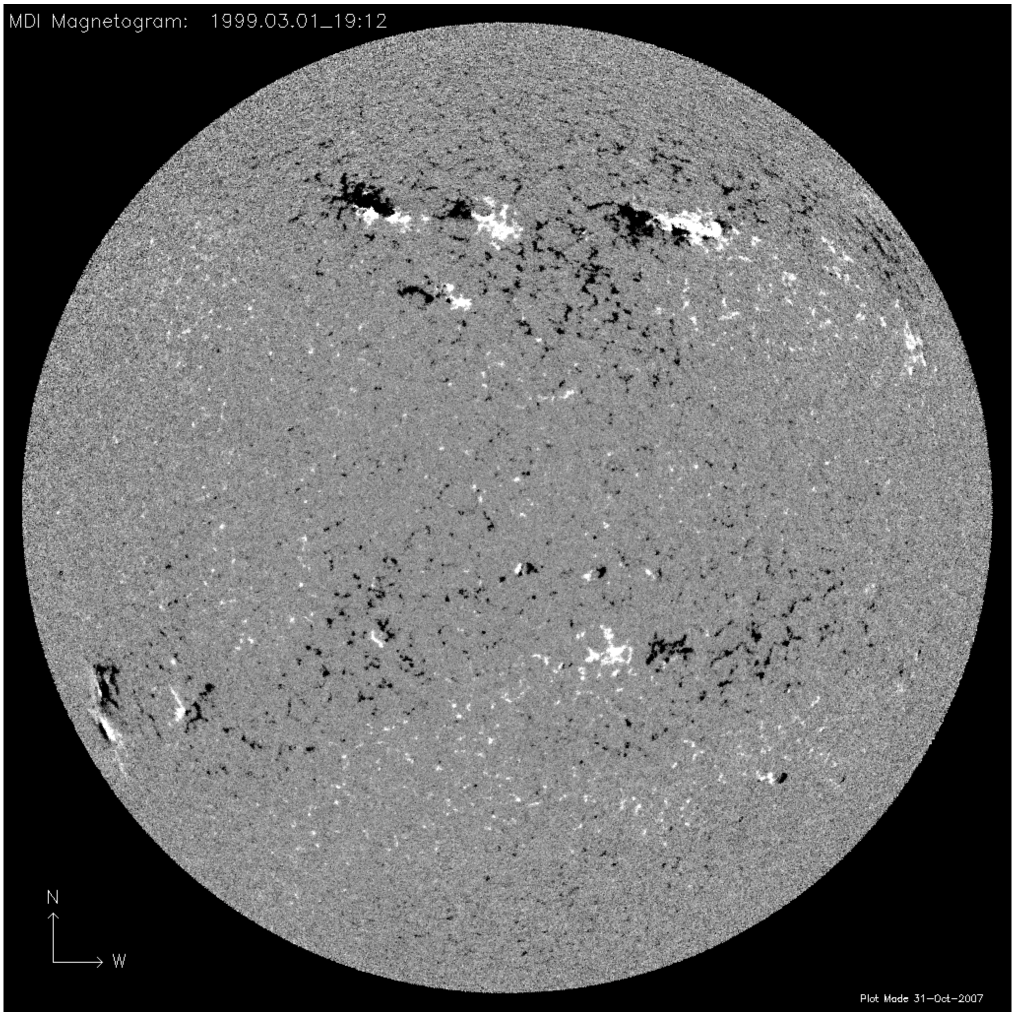
The Sun and Magnetic Fields

Intensitygram showing dark Sunspots

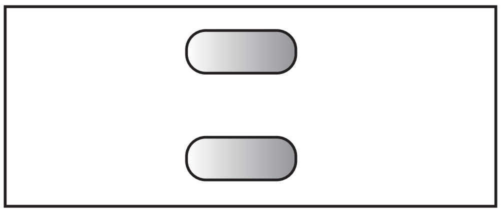
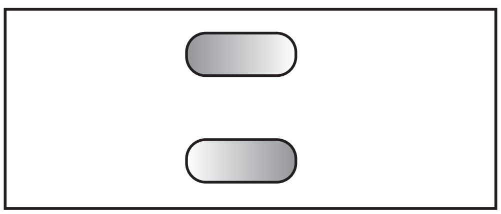
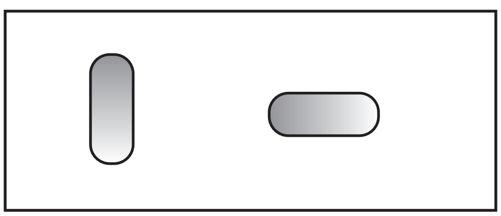
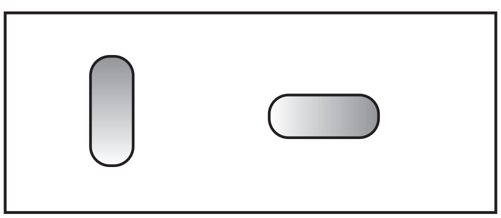


The Sun and Magnetic Fields

MDI Magnetogram showing Sunspot north (white) and south (black) poles.



The Sun and Magnetic Fields

	Magnet Alignment (Shaded from positive to negative)	Iron Filing Pattern
1		
2		
3		
4		
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Studying Light: Seeing the Invisible

Lesson plan and text adapted from Chandra X Ray Observatory Educational Material: http://chandra.harvard.edu/edu/formal/ems/ems_middleContents.html

Grades:
5 - 8

Objectives:
- Students will be able to describe the electromagnetic spectrum.
- Students will be able to explain that other types of light can be detected, even though we can't see it.

Description:
Students begin by using a clothesline to model a logarithmic scale. Then they add in the electromagnetic spectrum. Finally, students conduct several simple tests to detect other types of radiation.

Suggested Timing:
60 – 90 minutes.

National Standards
Content Standard E: As a result of their activities in grades 9 – 12, all students should develop an understanding of understanding science and technology, 5: Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

Content Standard B: As a result of their activities in grades 5 – 8, all students should develop an understanding of transfer of energy, 6: The Sun is a major source of energy for changes on Earth's surface. The Sun loses energy by emitting light. A tiny fraction of that light reaches Earth, transferring energy from the Sun to Earth. The Sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Content Standard D: As a result of their activities in grades 5 – 8, all students should develop an understanding of interactions of energy and mater: 2: Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays.

Vocabulary:
- Electromagnetic
- Spectrum
- Radiation
- Light
- Visible
- Ultra Violet
- Radio

Materials: (One per group)
- 5 meters of clothes line
- 14 clothes pins (tape also works)
- 14 numbered index cards (instructions in body of lesson)
- Labeled picture cards
- EM Spectrum picture cards
- IR remote control
- UV beads (www.teachersource.com)
- UV light or window
- Exponential Clothesline Conversion Table
- Cell phone or digital camera

Background Information:
The electromagnetic spectrum describes the range of energy, from low to high frequency or wavelength. This energy travels in waves and surrounds us at all times in one of many forms. The smaller and more frequent the wave, the higher energy it is. The longest, lowest frequency type of energy we can detect is radio waves. On the opposite side of the spectrum are gamma rays. Our eyes can detect a type of energy called visible light. Our sense of touch can detect infrared radiation as heat. The beads used in this lab detect ultraviolet radiation, a wave that has a bit more energy than visible light, in the range of 10nm to 400nm. These rays make it from the Sun through Earth's atmosphere to the ground, where humans experience them when they get a tan, Sunburn, or worse, skin cancer or blindness. The size of the UV waves is such that it can interact with the molecules of DNA inside a cell, disrupting it and causing cancer to begin. Wearing Sunscreen when going outside and avoiding purposeful tanning are key to preventing cancer.

Though each of these types of energy has different properties and effects, they are essentially the same thing: Electromagnetic Radiation. EM radiation is a stream of photons, massless particles traveling in a wave at the speed of light. The only difference between the different types of energy in the EM spectrum is how much energy the photons have. Photons with a higher energy have a smaller wavelength. Because Earth's atmosphere absorbs many kinds of radiation, including microwave, UV and Xrays, they cannot be studied from the ground. Scientists send spacecraft into orbit where they can study them and learn about their sources.

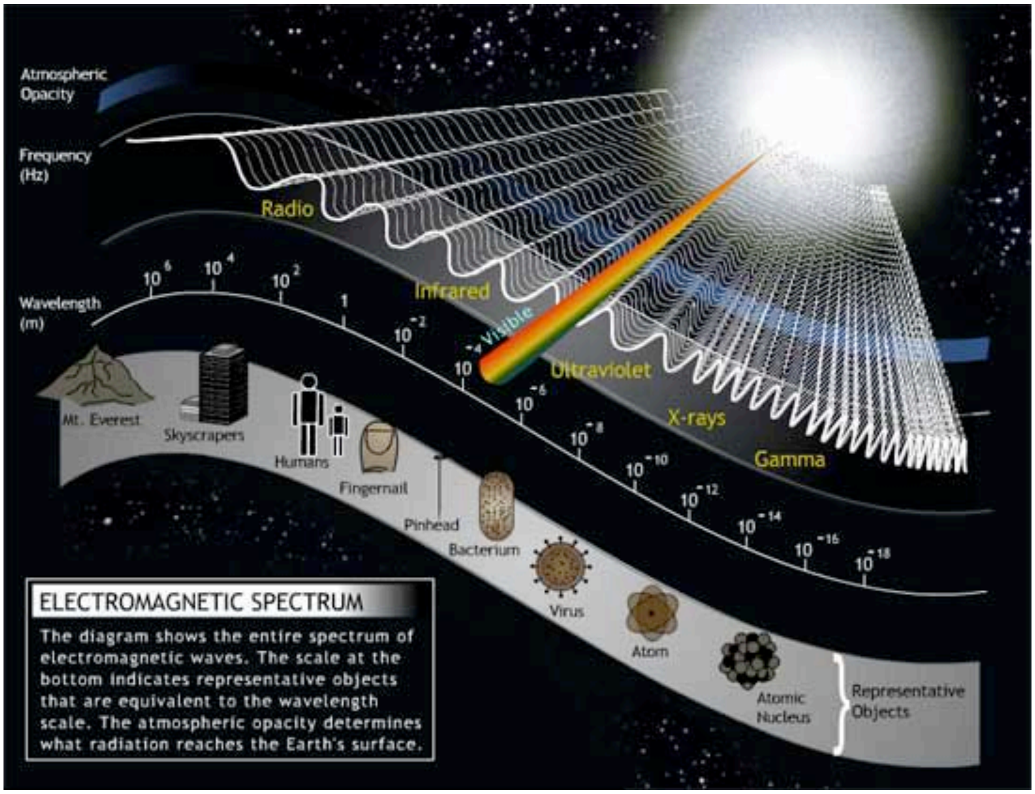


Image Source: http://www.nasa.gov/images/content/147517main_spectrum_large.jpg

Content:

Predict: (Engagement and assessing prior knowledge)

Give students the set of "picture cards." Tell them they have five minutes to arrange them, and then explain their reason for the arrangement they chose. Most students will reply that they chose size as a way to arrange the objects. Lead a discussion on ways to arrange a variety of things so that other people will understand how they relate to each other.

Explain that the electromagnetic spectrum is an arrangement of energy waves from low to high frequency. In the next activity they will be exploring how that scale looks.

Method: (Body of the lesson)

Many students have difficulty expressing large numbers using exponential notation. The exponential clothesline helps to pre-assess student understanding of exponents by providing a visual representation of exponential notation (powers of ten). The Exponential Clothesline Conversion Table will also pre-assess and refresh student understanding of fractions and decimals.

Provide each group of students with the following materials:

One 5-meter piece of clothesline (or string)
Fourteen (14) clothespins (or paper clips)
Fourteen (14) index cards with the following numbers identified as follows:
0 written in red,
1, 2, and 3, in blue,
10^1, 10^2, 10^3, 10^6, 10^9, and 10^{12} in green,
10^{-1}, 10^{-2}, 10^{-3}, and 10^{-4} in black

Numbers written in black on different colored index cards are more visual, and any incorrectly placed numbers are immediately recognizable in a large classroom.

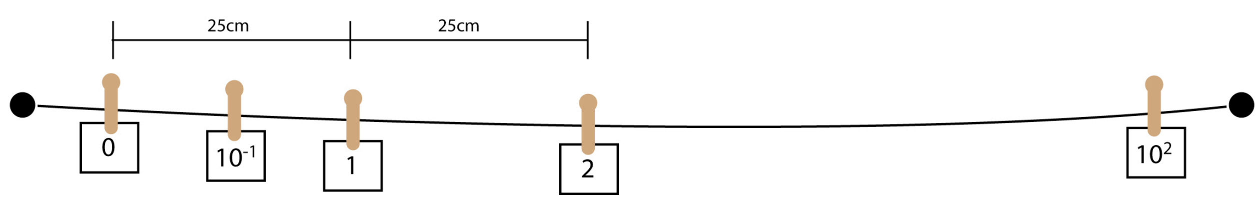
Depending on your group, you may wish to provide some larger (or smaller) exponents or include a set of numbers with exponents such as 2×10^0, 2×10^1, 2×10^2 and 2×10^{-2}.

Step 1: The Numbered Scale

Give each group of students the clothesline, clothespins, and a set of numbered index cards. Randomly distribute the cards as evenly as possible within each group. Have the students string the clothesline, and ask the student in each group with the number 0 to attach that index card approximately one-sixth of the way from the left end of the clothesline. The students with the number 1 should attach it 25-cm to the right of the number 0.

Explain to students that their clothesline represents a number line and that they are going to add whole numbers and numbers expressed in scientific notation to the number line. Ask the students who have numbers 2 and 3 in each group to place their numbers on the clothesline.

Most students will correctly place whole numbers on the number line. Give the students the task of placing the remaining numbers on the number line in their correct locations. (It is important to explain to your students that this number line is not to scale.)



Most groups will discuss and accurately place 10^1, 10^2, 10^3, 10^6, 10^9, and 10^{12} and other higher powers of ten; however when they begin to place the negative exponents on the clothesline, most students will place them to the left of 0, which is a common mistake.

The negative exponents actually fall between 0 and 1. Encourage the students to make changes if they think any of the numbers are not in the correct order. If any of the groups think that their number lines are correct and there are still numbers placed out of sequence, hand out the Exponential Clothesline Conversion Table. The purpose of the conversions is to express the exponents as whole numbers, fractions and decimals. After the final conversion of the exponents to decimals, students who have the negative exponents incorrectly placed usually begin to see that negative exponents are still greater than 0 and rearrange their number lines accordingly.

Step 2: Adding EM Radiation
Give students the EM spectrum cards (attached). Explain that the frequency range printed on the card is the type of radiation's location on the scale. Have students find the location of each type of radiation along the clothesline and attach the card in the correct spot.

Models of the electromagnetic spectrum similar to the one pictured in the background information are used extensively in textbooks and on posters, and like all other models it contains distortions. The model is extremely useful for showing the frequencies of the different bands of electromagnetic radiation (EMR), and the relationships between frequency and wavelength. However, this is an exponential model, and distorts the actual width of the different bands of radiation.

Use this activity to enter into a discussion about what scientific notation is and why it is useful, as well as their reaction to how the EM spectrum fits into it versus their prior knowledge.

Step 3: Detecting the Invisible
Ask students too look at the spectrum they just built and brainstorm ways we have of detecting those other types of radiation. Give them a hint by reminding them that their eyes detect visible light.

Once they've created their list, have them do the following demos:

1. Place UV beads in the Sun and observe the color change.
    a. One extension would be to paint a few with Sunscreen to show that the UV rays are being blocked.
2. Point an older remote control at a cell phone or digital camera. The infrared beam will be visible through the camera. The camera acts as a detector for that kind of radiation.
    a. CCD's in digital cameras pick up the IR from the remote control as "noise" in the image.

Live-It: (Assessment/application assignment)

Have students answer the following questions: What is the Electromagnetic Spectrum? How do we know these types of energy exist? How do we use EM energy in our daily life?

Have students make a mnemonic out of the different types of EM radiation to help them remember it in order.

Extension:

Have students go online and observe various objects in different wavelengths, comparing and contrasting features visible in each of them: Available at "Cool Cosmos"
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/

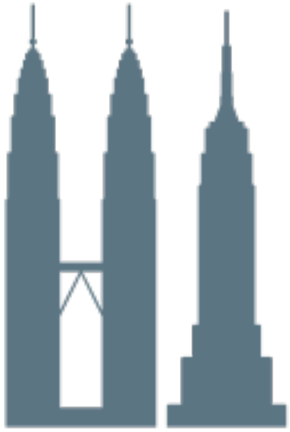
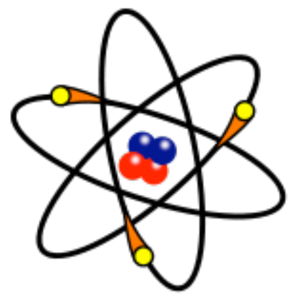
Resources:

Chandra Modeling the EM Spectrum:
http://chandra.harvard.edu/edu/formal/ems/ems_middleContents.html

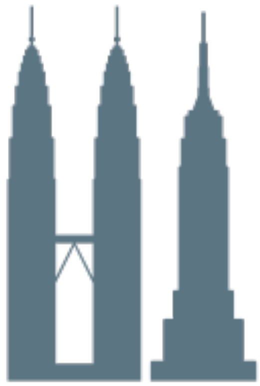
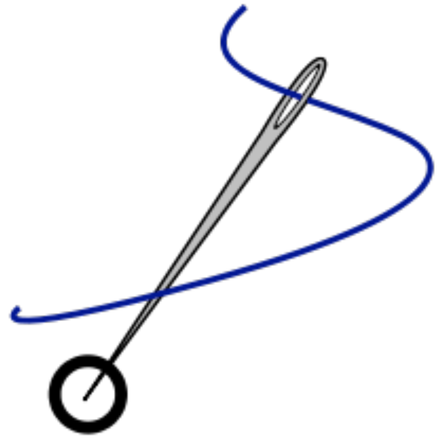
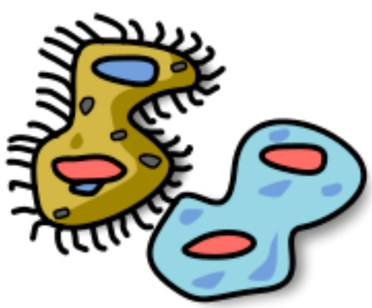
EM Spectrum Large Image:
http://upload.wikimedia.org/wikipedia/commons/c/cf/EM_Spectrum_Properties_edit.svg

Cool Cosmos:
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/

Picture Cards – Studying Light: Seeing the Invisible

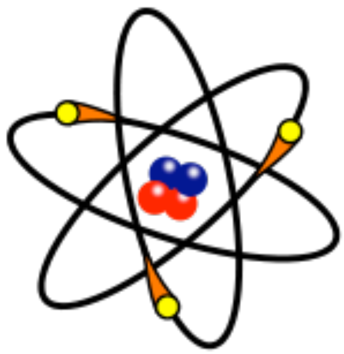
 Buildings	 Humans	 Butterflies
 Needle Point	 Molecules	 Atoms

EM Spectrum Picture Cards – Studying Light: Seeing the Invisible

Radio 10^{3}  Buildings	**Infrared** 10^{-5}  Needle Point
Visible 0.5×10^{-6}  Protozoans	**Ultraviolet** 10^{-8}  Molecules

X-ray

10^{-10}



Atoms

Gamma ray

10^{-12}

Atomic Nuclei

Microwave

10^{-2}

Humans Butterflies

The Exponential Clothesline Conversion Table

Index Card	Number	Fraction	Decimals
0			
1			
2			
3			
10^1			
10^2			
10^3			
10^6			
10^9			
10^{12}			
10^{-1}			
10^{-2}			
10^{-3}			
10^{-4}			

The Exponential Clothesline Answer Key

Index Card	Number	Fraction	Decimals
0			
1	10^0	1/1	1.0
2	2×10^0	2/1	2.0
3	3×10^0	3/1	3.0
10^1	10	10/1	10.0
10^2	100	100/1	100.0
10^3	1000	1000/1	1000.0
10^6	1000000	1000000/1	1,000,000.0
10^9	1000000000	1000000000/1	1,000,000,000.0
10^{12}	1000000000000	1000000000000/1	1,000,000,000,000.0
10^{-1}	$1/10^1$	1/10	.1
10^{-2}	$1/10^2$	1/100	.01
10^{-3}	$1/10^3$	1/1000	.001
10^{-4}	$1/10^4$	1/10000	.0001

NOTES:

Studying Light: Spectroscopes

Grades:
5 - 8

Objectives:

- Students will be able to explain that visible light can be split into a spectrum, and that different elements give off different spectrum when excited.

Description:
Students build their own spectroscopes, learn about graphing the spectra, and then identify elements in gas tubes using their spectra. The activity concludes with students looking at spectra of celestial objects.

Suggested Timing:
25 – 30 minutes.

National Standards
Content Standard B: As a result of their activities in grades 5 – 8, all students should develop an understanding of transfer of energy, 6: The Sun is a major source of energy for changes on Earth's surface. The Sun loses energy by emitting light. A tiny fraction of that light reaches Earth, transferring energy from the Sun to Earth. The Sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Vocabulary:

- Electromagnetic Spectrum
- Radiation
- Light
- Visible
- Emission

Materials: (For class)

- Spectrum light tubes and power source (Spectra for other elements should you choose to use them can be found here: http://spiff.rit.edu/classes/phys312/workshops/w10b/spectra/spec_rev_orientation.gif)
- Helium, Hydrogen, Nitrogen and Neon (One per student)
- Cereal box
- Scissors
- Tape
- Diffraction gradients (www.rainbowsymphony.com)
- Worksheets

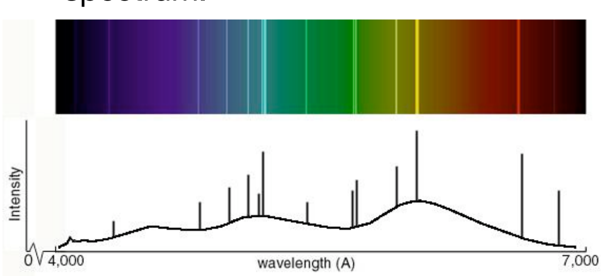
Background Information:

Spectroscopy is the study of light dispersed into its color components. Examining their spectra can identify individual elements. Astronomers use the same technique. Earth is four light years away from the closest star, making it impossible for us to visit. By looking at the spectra from stars or galaxies scientists can learn about their composition, temperature, speed and distance, without having to travel to them

Astronomers generally do not look through their large telescopes. Most of the time large telescopes are collecting light for a spectrograph, which spreads the light out into a rainbow. Each kind of atom or ion has certain special wavelengths which it can absorb or emit. Atoms absorbing energy will create dark lines on the spectra, while atoms emitting energy will produce bright lines on the spectra like those in the image below. These can be used to identify the atoms that make up a star.

Astronomers do not actually use color film to take a color picture of the spectrum, for several reasons:

- Color film is less sensitive than black and white.
- Color film does a very poor job of representing the continuous range of colors in a spectrum. It takes a lot of work to make a decent printout or display of a spectrum.
- While a picture may be worth a thousand words, a graph showing brightness *vs.* wavelength has much more quantitative information than a picture of the spectrum.



Astronomers make graphs of their spectra, with the y-axis showing the brightness, while the x-axis shows the wavelength. In the figure above the graph is aligned just below the picture of the spectrum.

Credit:
http://www.astro.ucla.edu/~wright/fluxplot.html, 2009

Content:

Predict: (Engagement and assessing prior knowledge)

Ask: How can you learn about something if you are too far away to reach it?

Place an object at the front of the classroom, out of reach of the students. Give them a few minutes brainstorm every way they can think of to learn about the object. After taking some suggestions from the class, conclude that the only way they can learn about it is to look at the object from afar.

Ask: What is allowing us to look at the object? Discuss that the light bouncing off of the object into our eyes is how we can gain any knowledge about the properties of the object.

Method: (Body of the lesson)

Tell students that astronomers use light to study objects in space, and that they are going to construct a tool that will let them study light like astronomers do.

Ask: Have you ever seen a rainbow? What is it? Discuss that a rainbow is visible white light broken into its color components. Tell students that light coming from unique sources can be broken up into its color components and studied. Light emitted by gas that has been excited has its own distinct spectra. Looking at the spectra can identify elements in stars, nebulae, and galaxies. Show students a sample image of a spectra and show them how to draw a simple graph to represent it.

Hand out cereal box spectroscope instructions, worksheet and materials. Assist students in construction as needed.

Set up and turn on Spectrum light tubes. Place each one in a large black box, or make the room as dark as possible. Label them “Mystery Gas #1, Mystery Gas #2 and so on. The gas tubes can be set up ahead of time, but beware of power cords as potential tripping hazards. Warn the students that the gas tubes can get very hot and they shouldn’t touch them.

Instruct students to examine the spectra emitted from each tube through their spectroscope, and match it to the spectra in part 1 their worksheet. Try and identify the contents of each gas tube.

Part 2 of their worksheets guides students in “graphing” spectra like scientists do. The Y axis is intensity while the X axis is wavelength.

Students are to examine each spectra, then draw a graph in the adjacent box, creating spikes in the graph for each emission line.

Live-It: (Assessment/application assignment)

Have students answer the following question in two complete paragraphs: What does a rainbow have to do with outer space? (Encourage the use of diagrams)

Extension:

Visit: http://imagine.gsfc.nasa.gov/docs/teachers/hera/overview.html and download the HERA for students software. After completing the tutorial students will be able to manipulate the same data scientists work with, using the same software they developed. All data is in X-Ray taken by the Rossi X-Ray Timing Explorer satellite.

Resources:

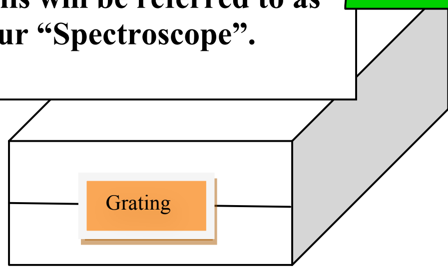
Analyze data with HERA for Students:
http://imagine.gsfc.nasa.gov/docs/teachers/hera/overview.html

Intro to Spectroscopy
http://loke.as.arizona.edu/~ckulesa/camp/spectroscopy_intro.html

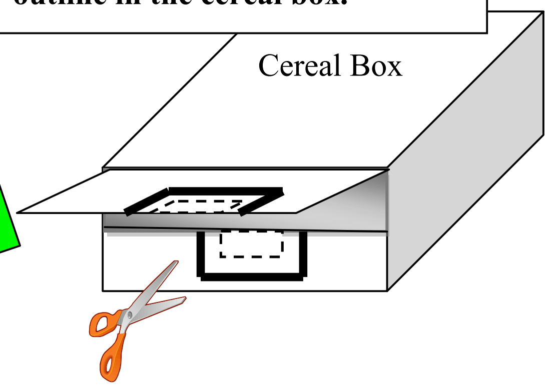
Visible Spectra of the Elements
http://www.umop.net/spctelem.htm

Making your CEREALBOX SPECTROSCOPE

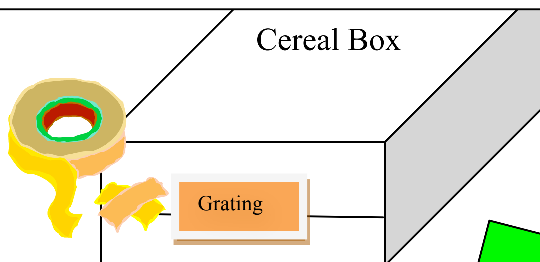
1. Select one end of the cereal box, and close the flaps. Place a diffraction grating on this end and outline it with the sharpie. This will be referred to as the front of your "Spectroscope".



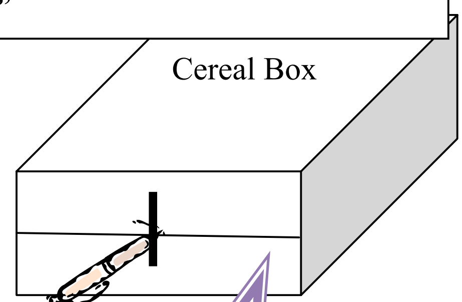
2. Open the flaps and cut a hole smaller than the size of your outline in the cereal box.



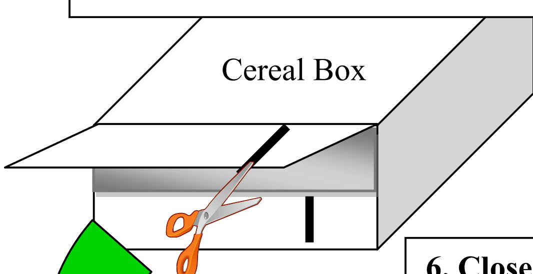
3. Tape the cereal box flaps closed. Arrange your diffraction grating right side up (so you can read the label), then tape it over the hole you just cut. Make sure you can look through the grating and see inside the box.



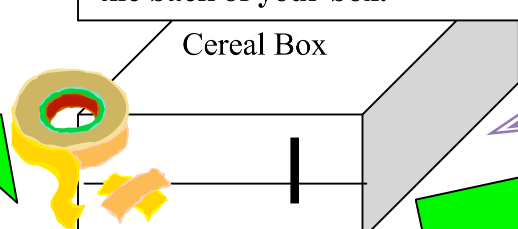
4. Rotate the box around so you are now looking at the opposite end. (This will be the back of your "Spectroscope"). Close the two flaps and draw a line down the center (top to bottom, not side to side). The line should be directly opposite the diffraction grating, and centered.



5. Cut along the mark you just made, making a very, very narrow slit in the box.



6. Close and tape the flaps on the back of your box.



You're done!! Look through the grating in your spectroscope to see the light spectrum!

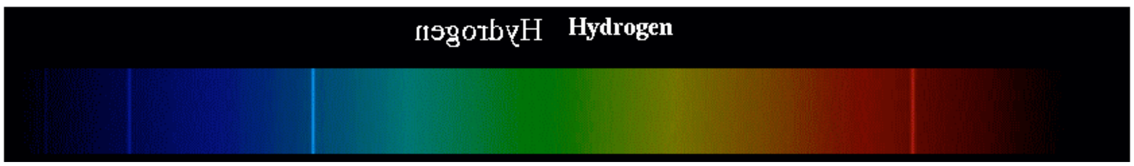
Studying Light: Spectroscopes

Name: _______________________ **Date:** _______________

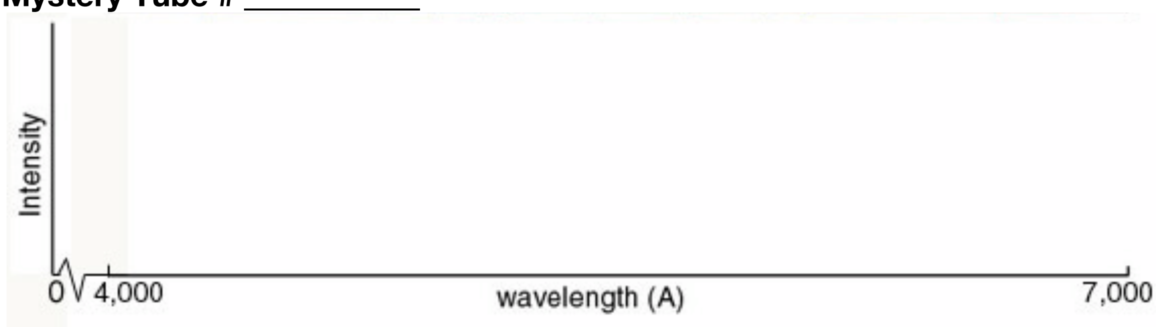
Identify each of the mystery gas tubes your teacher has provided for you using your spectroscope and the spectra below.

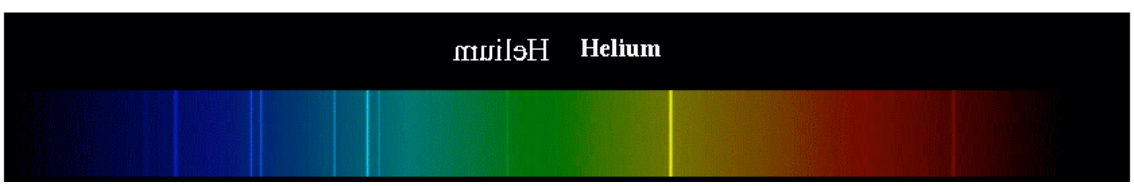
Once you have identified each gas tube, graph it's spectra in the box below.

Remember: "Intensity" or "Brightness" is recorded on the Y axis, and the wavelength is along the X axis.

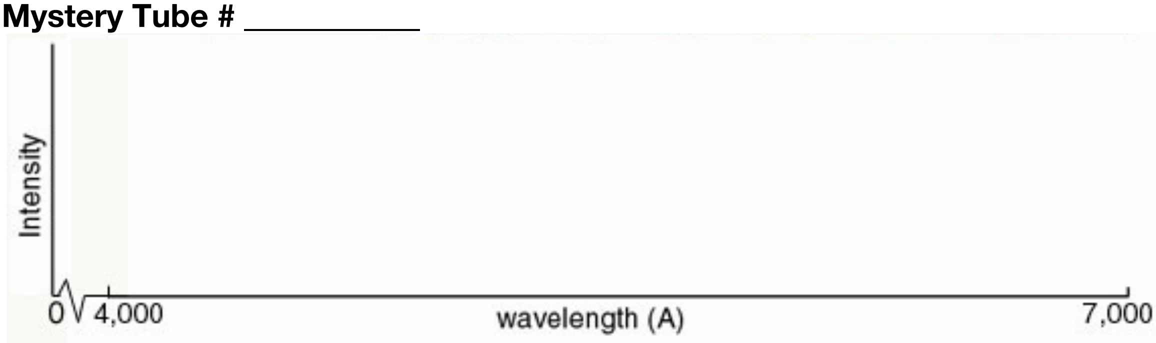


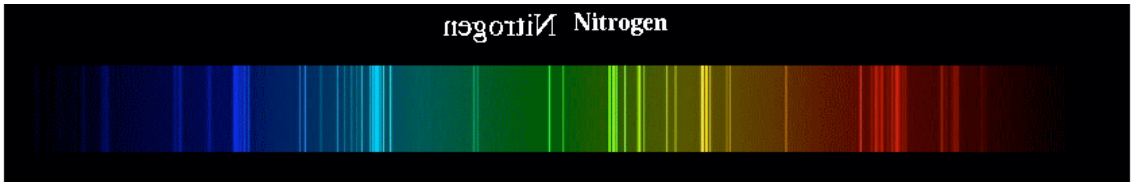
Mystery Tube # ___________



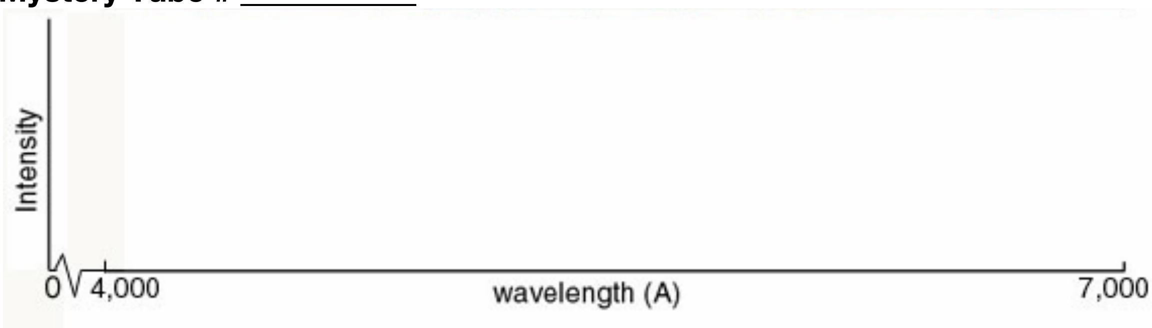


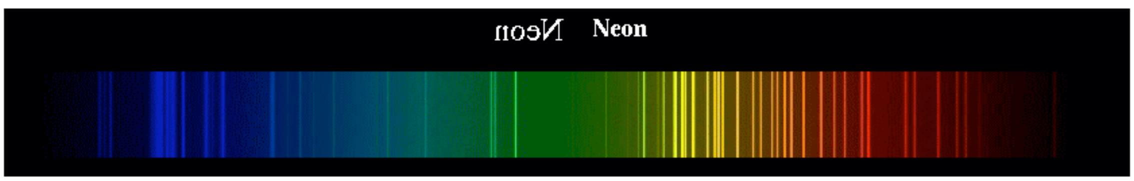
Mystery Tube # ___________





Mystery Tube # __________





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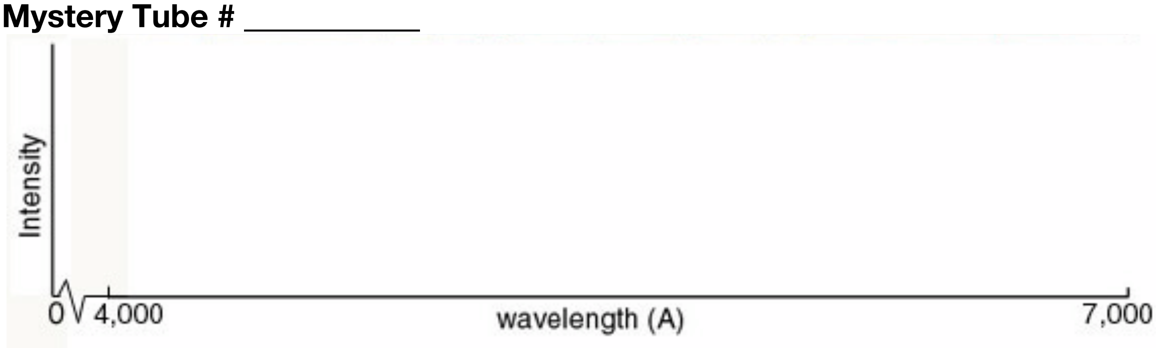


NOTES:

Sounds of the Sun

Grades:
5 - 8

Objectives:
- Students will be able to explain the Doppler effect and the relationship between speed and direction of source, and frequency of sound waves.
- Students will be able to explain how the Doppler shift can be used to gather information about objects in space including the Sun.
- Students will be able to calculate the change in frequency of sound emitted by a moving object using the Doppler equations.

Description:
Students begin by simulating the noise made by a passing siren. After leaning that the change in pitch results from movement they investigate the definition of frequency. Students conclude by calculating the change in frequency heard when they simulated the noise of the passing siren, and learn how this applies to light and the study of astronomy.

Suggested Timing:
30 – 45 minutes.

National Standards
Content Standard B: As a result of their activities in grades 5 – 8, all students should develop an understanding of transfer of energy, 6: The Sun is a major source of energy for changes on Earth's surface. The Sun loses energy by emitting light. A tiny fraction of that light reaches Earth, transferring energy from the Sun to Earth. The Sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Vocabulary:
- Frequency
- Wave
- Source
- Doppler Effect

Materials: (One per group)

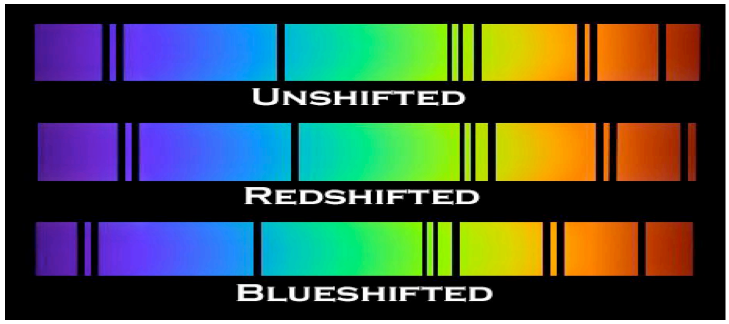
- Doppler ball
- Meter Stick
- Calculators
- Ramp, 4ft long.
- Small balls (malted milk balls or marbles)
- Concentric paper rings
- Cards – red on one side, blue on the other.

Background Information:

The Doppler effect of sound is something that we are familiar with from our everyday experience. When something making a loud noise (e.g., a car horn, a fire truck siren or a train whistle) moves past us quickly, the sound changes because the sound waves reach us differently than if everything was sitting still. This effect happens with all types of waves, and is a very useful tool.

Let's think a bit more about why waves appear different if things are moving about. Imagine you are a lifeguard in a rowboat a bit off shore guarding all the swimmers at the beach, and that there are some waves evenly spaced apart, moving directly towards the beach. Every few seconds, your rowboat is rocked by a wave. What would happen if you started to row away from the beach, to/ward the incoming waves? Would the waves rock your boat more or less frequently? What if you were done working and you were rowing in toward shore? This is the essence of the Doppler effect: that waves will be more frequent if you are moving toward them or if the source of the waves is moving toward you, and they will seem less frequent if the source and the observer are moving apart.

The Doppler effect was first proposed by Christian Andreas Doppler, the man it is named after. On May 25, 1842 at the Royal Bohemian Society in Prague he presented the paper "On the Colored Light of the Double Stars and Certain Other Stars of the Heavens," where he first predicted that motion could effect the color or frequency of light. Doppler did not get all the details right, nor were the instruments of that era accurate enough to test his theory with light. However, his central idea was right and that is why over 160 years later we all recognize his name. One of the first experiments to test the Doppler effect involved having musicians play a certain note while sitting on a moving train and having another musician record what notes he heard as they approached and retreated.



The diagram above illustrates how our perception of light changes depending on whether the source of the light is stationary, moving towards us, or moving away from us. On the top of the Figure we see that if the source is still, an observer will just see the light with the same wavelength and frequency as was emitted. However, in the middle and bottom of the Figure we see what happens if the source is moving. As the source moves, successive waves ahead of the source are crowded together. That is, each new wave begins a bit further forward than if the source stayed in one place. To an observer ahead of the source this behavior will make the source's wavelength appear shorter, which means its frequency will appear higher. This change to a higher frequency/shorter wavelength is called a blueshift. However, if the observer is behind the moving source, then the opposite will happen. The successive waves will be spread out and the light will appear to have a longer wavelength and a lower frequency. This change to a lower frequency/longer wavelength is called a redshift. (Credit: Reid Sherman, University of Chicago)

Content:

Predict: (Engagement and assessing prior knowledge)

Ask students if they have ever heard a fire truck/police/ambulance pass. What did it sound like? Encourage the class to imitate the noise, or do it yourself, making sure to emphasize a change in pitch as the vehicle would pass. A recording can also be played if the technology is accessible.

Explain their task: To **reproduce** and **measure** this phenomenon to the point where their calculations can predict it.

Give students buzzer balls and let them play for a bit. Direct them to make observations in their notebooks.

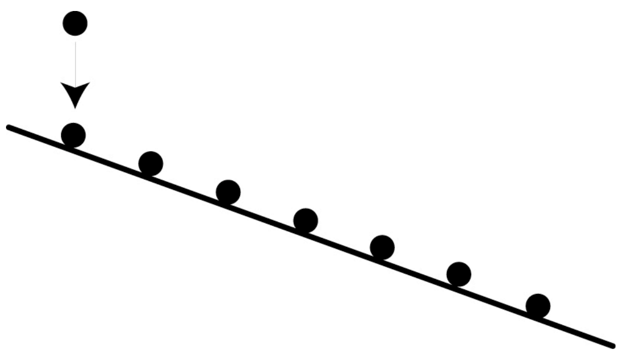
After a few minutes discuss those observations. Ask: What did you have to do to simulate the sound? Answers will vary, questions students until they conclude that the buzzer ball had to be moving to create the desired effect.

Discuss the observation that the sound got “higher” as the ball swung by, and “lower” after it passed. Tell students that the “Frequency” changed.

Method: (Body of the lesson)

Discuss definition of “frequency.” Ask students to postulate a definition. Discuss the meaning of the word. Conclude by giving the following definition:

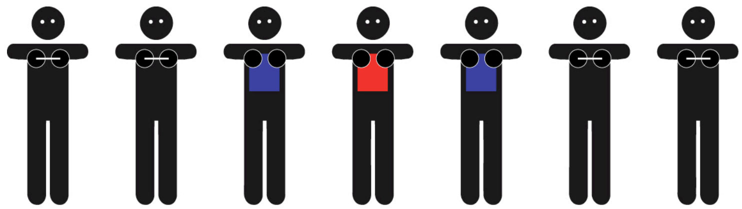
Frequency = wavelengths per unit time.
Or
Frequency = number of peaks or troughs passing a point in a given time.



Have students gather around a ramp and count the “frequency” of balls dropped by a still source (the teachers hand), a proceeding source, and a receding source. Starting at the top of the ramp, drop several balls at regular intervals, keeping your hand in the same location. Have students make observations about the frequency of the balls hitting the bottom of the ramp. Repeat, this time moving your hand towards the bottom of the ramp. Do this once more, starting at the middle of the ramp and moving your hand up towards to top.

- Question students to and lead them to observe that the balls are closer together when dropped by a source moving towards them, and farther apart when dropped by a source moving away from them.
- Closer together results in a higher frequency.
- Farther apart results in a lower frequency.
- Tell students that with sound we measure how frequently the crest of a sound wave passes us.
- Discuss the changes in sound that higher and lower frequency indicates.

To solidify this with students show them concentric rings (of paper, embroidery hoops, anything round and of decreasing size,) arranged one inside the other to look like ripples in a pond. This can be done on a table or overhead projector. Place your finger in the center and explain that it is the “source” of the sound and the rings are the waves. Slowly move your finger towards the students without removing it from the table/projector. The rings will gather in the direction of movement. Question students and have them explain that this shows that a moving source has higher frequency waves preceding it, and lower frequency waves following it. Ask them what they would hear standing in front of it, and what they would hear standing behind it.



Go over the equation for calculating the frequency of a moving source:

Equation: Source moving towards you:

f_o=f (vs /(vs - v))

If the source is moving AWAY from you add a positive sign (+) to its value (v).

Variables:

f = source frequency in Hertz (Hz) = 2,800 Hz

f_o = observed frequency (Hz) = ?

v = speed of source = ?

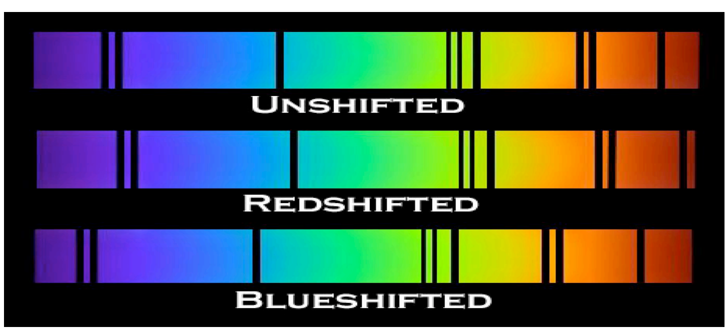
vs = speed of sound wave = 343 m/s.

Tell them they must begin by calculating the speed of the ball. If students are having trouble, remind them that velocity is distance over time, and that the distance the ball is traveling when they swing it is the circumference of a circle, or pi r 2 Hand out meter sticks and have them do so as they swing the ball once per second.

Plug in the rest of the variables into the equations and answer the questions. This is a good opportunity to show them that equations in science aren't simply numbers and letters, but that each variable represents a physical phenomenon.

Ask: What happens when it speeds up? Have them try it with their ball, then apply the calculations. What happens when it slows down?

Explain that light is a wave with frequency as well. Describe how the spectrum of light can appear "shifted" in one direction or the other. Show students the image below:

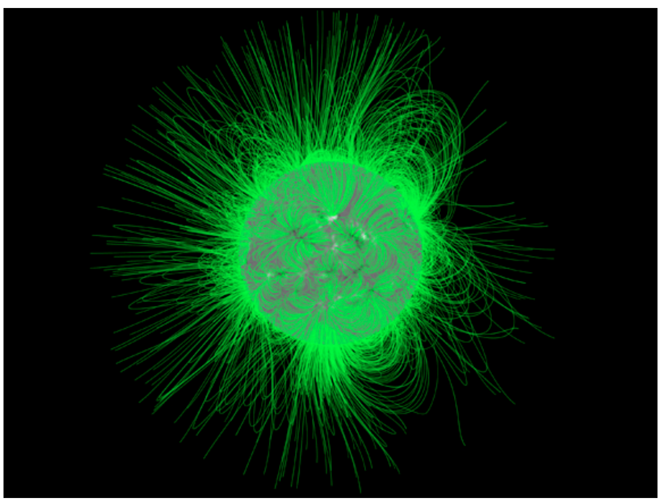


Explain that blue and purple are at the high frequency/high energy end of the spectrum, and red is at the low frequency end of the spectrum.

Ask: If the light source is moving towards you, is it redshifted, or blueshifted? (Blueshifted)

Live-It: (Application assignment)

To explain how the Solar Dynamics Observatory (SDO) will be using the Doppler Effect to study the Sun, hand out cards colored red on the front and blue on the back. Instruct students to stand in a circle and create a horizontal wave with their hands. When their hands move out flip the card to the blue side, when they move back in flip to the red side. Let students observe the color changes as the wave propagates around the circle. Explain the Helioseismic Magnetic Imager (HMI) instrument on SDO will be using the Doppler Effect to find waves on the Sun, then measure their velocities and track them. Studying the waves on the Sun will allow us to see what the interior is like, much like earthquakes on earth tell us about the interior of our planet.



Extension:

Students can research other technologies that use the Doppler Effect, or the Hubble Constant and the proof of an expanding universe.

Resources:

The Solar Dynamics Observatory
http://sdo.gsfc.nasa.gov/

Helioseismic Magnetic Imager on Youtube
http://www.youtube.com/watch?v=Pj29_fdfOlo&feature=player_embedded

SDO - Solar Dynamics Observatory

Our Eye On the Sun Secondary Learning Unit
EG-2010-01-032-GSFC

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http://sdo.gsfc.nasa.gov/epo/educators/